17

3d Congress, 2d Session.
HOUSE OF REPRESENTATIVES.
Document No. 762.

INAL REPORT, WATERWAY FROM LOCKPORT, ILL., TO THE MOUTH OF THE ILLINOIS RIVER.

LETTER

FROM

HE SECRETARY OF WAR,

TRANSMITTING,

TH A LETTER FROM THE CHIEF OF ENGINEERS, FINAL REPORT
Y A SPECIAL BOARD OF ENGINEERS UPON WATERWAY FROM
OCKPORT, ILL., BY WAY OF THE DES PLAINES AND ILLINOIS
IVERS, TO THE MOUTH OF SAID ILLINOIS RIVER, AND CERTAIN
ELATED SUBJECTS.

RUARY 20, 1914.—Referred to the Committee on Rivers and Harbors and ordered to be printed, with illustrations.

War Department,
Washington, February 18, 1914.

e Speaker of the House of Representatives.

ir: I have the honor to transmit herewith a letter from the Act-
n Chief of Engineers, United States Army, dated 17th instant,
ether with copy of final report by a special board of engineers,
ed August 15, 1913, with maps, upon waterway from Lockport,
l by way of the Des Plaines and Illinois Rivers, to the mouth of
nois River, the construction of dams at or near Jefferson Barracks
r Commerce, and certain related subjects, made in compliance
h the provisions of the river and harbor act approved June 25, 1910.

Very respectfully,

Lindley M. Garrison,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, February 17, 1914

From: The Chief of Engineers, United States Army.
To: The Secretary of War.
Subject: Waterway from Lockport, Ill., by way of the Des Plai
and Illinois Rivers to the mouth of Illinois River.

1. There is submitted herewith, for transmission to Congress, fi
report, dated August 15, 1913, with maps, by a special board
pointed pursuant to the requirements of the river and harbor
approved June 25, 1910, to consider and report upon a waterv
from Lockport, Ill., by way of the Des Plaines and Illinois Rivers
the mouth of Illinois River, the construction of dams at or n
Jefferson Barracks and Commerce, and certain related subjects.

2. Under date of November 1, 1910, the special board submitte
preliminary report, which is printed in House Document No. 10
Sixty-first Congress, third session, and under date of January 23, 19
it submitted a further report, printed in House Document No. 13
Sixty-first Congress, third session, covering five of the nine questi
specifically mentioned in the act. Attention is invited to th
reports for detailed information regarding the project recommen
for the construction of this waterway. The subjects treated in
present report of the special board include such measures as may
required to properly preserve the levels of the Great Lakes, the in
ence on volume and height of waters in the Mississippi River be
Cairo, the effect upon the climate of the Lake States by a chang
the natural currents of Lake Michigan, and the improvement of
Mississippi River between the mouth of the Illinois River and
mouth of the Ohio River by the construction of a dam at or n
Jefferson Barracks, and a dam at or near Commerce, and the deve
ment of water power incidentally created by such dams.

3. The special board finds that the diversion of 10,000 cubic
of water per second through the Chicago Drainage Canal would lo
the water surface at mean lake level 0.465 foot in Lakes Huron
Michigan, 0.448 foot in Lake Erie, and 0.431 foot in Lake Onta
It proposes the construction of submerged weirs in Niagara Rive
hold up the level of Lake Erie and submerged weirs in St. Clair R
to hold up the level of Lakes Michigan and Huron, at a total estim
cost of $475,000, with $15,000 annually for maintenance. The in
ence on the volume of the Mississippi River due to any diversion f
Lake Michigan will be an increase approximately equal to the amo
of water diverted.

4. The effect upon gauge height will be small, even at low stages,
at high stages it would scarcely be appreciable and of no importa
The effect on the climate of the Lake States, caused by the diver
of 10,000 second-feet of water through the Chicago Drainage Ca
whether beneficial or injurious, would be so small that it could no
measured by the most delicate instruments. The special b
reports that the construction of dams at or near Jefferson Barr
and Commerce is not necessary for the execution of existing proj
for the Illinois and Mississippi Rivers, nor of the projects rec
mended in the partial report printed in House Document No. 1
Sixty-first Congress, third session. The work would be enormo

xpensive and not justified by resulting benefits to commerce and avigation, nor by the returns from water-power development.

5. The recommendations of the special board are contained in the artial report referred to above. It states that since the submission that report nothing has developed to require any changes in the atements and conclusions therein given.

6. This final report has been referred, as required by law, to the oard of Engineers for Rivers and Harbors, and attention is invited its report herewith, dated December 16, 1913, which gives a brief alysis of the entire investigation. The board concurs in general ith the views of the special board, though with the information now ailable it is not prepared to indorse the discussion in all its details. bject to certain conditions fully explained in its report, the board commends the adoption of the project presented by the special ard, which involves an original outlay by the United States of ,050,000 for the Illinois River and $3,710,000 for the Mississippi ver, or a total of $4,760,000 for a navigable channel 8 feet deep m Utica to St. Louis.

Edw. Burr,
Colonel, Corps of Engineers,
Acting Chief of Engineers.

PORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS.

[Second indorsement.]

Board of Engineers for Rivers and Harbors,
December 16, 1913.

The Chief of Engineers, United States Army:

1. The Board of Engineers for Rivers and Harbors has had under sideration the final report of the special board of engineers, sub-tted pursuant to the following item contained in section 1 of the er and harbor act approved June 25, 1910:

> or the construction of a waterway from Lockport, Ill., by way of the Desplaines Illinois Rivers to the mouth of said Illinois River, $1,000,000. The Secretary of shall appoint a board of five members, to be composed of four engineer officers of Army and one civil engineer taken from civil life. The president of the board of members authorized under act of March 2, 1907, to examine the Mississippi er below St. Louis and report to Congress on the project of a 14-foot channel shall a member of and president of the board herein provided for. Said board shall ort upon the feasibility of such waterway, and the most advisable depth and ensions therefor, in case the same is recommended; also upon such measures as be required to properly preserve the levels of the Great Lakes and to compen-, so far as practicable for the diminished level in said lakes and the connecting ers thereof by reason of any diversion of water from Lake Michigan for the main-nce of the proposed waterway herein described, or diversion for any other purpose further, also, upon the influence on volume and height of waters in the Missis-i River below Cairo; and further, also, as to the effect upon the climate of the e States by a change in the natural currents of Lake Michigan. The board shall, full conference with the authorized agency of the State of Illinois, submit a rt upon the extent to which the United States may properly cooperate with the e of Illinois in securing the construction of a navigable waterway from Lockport he mouth of the Illinois River in conjunction with the development of water er by said State between Lockport and Utica, for which the people of the State llinois have authorized their general assembly to appropriate $20,000,000; the rt shall state the extent and character of the cooperation recommended and the litions considered necessary in connection therewith to fully protect the interests he United States. Should the board consider cooperation to be advisable, the

report herein called for shall include plans and estimates of cost of the work rec
mended to be done by the United States alone or in cooperation with the Stat
Illinois; and until these plans and estimates have been submitted and a projec
the improvement adopted by Congress the appropriation of $1,000,000 herein m
shall not be available for expenditure. The board also shall consider and re
upon the improvement of the Mississippi between the mouth of the Illinois River
the mouth of the Ohio River by the construction of a dam at or near Jefferson
racks and a dam at or near Commerce, and the development of water power inci
tally created by such dams. In the performance of its duties the board may
sider all reports heretofore made; and the force, plant, and records of the Mississ
River Commission and the several engineer districts between Chicago and Cairo s
be available for the use of the board. The members of the board herein author
shall be entitled to compensation at the rate of $6,000 per annum, but the off
salary of any officer appointed on said board from the Engineer Corps of the A
shall be deducted from the compensation provided for in this act. For salaries
expenses of said board, including all necessary clerical and other personal serv
there is hereby appropriated the sum of $50,000. The reports herein called for s
be submitted to the Chief of Engineers not later than November 1, 1910, reviewe
the Board of Engineers for Rivers and Harbors, and submitted to Congress not
than the first Monday in December, 1910.

2. Complying with the requirements of the above item, the spe
board under date of November 1, 1910, submitted a preliminary
port outlining the steps being taken to procure the necessary d
and under date of January 23, 1911, it submitted a further rep
covering five of the nine questions specifically mentioned in the
The former report is printed in House Document No. 1061, Sixty-
Congress, third session, and the latter in House Document No. 1
of the same Congress and session. The report now under consid
tion covers the remaining four questions, but for convenience
reference, a summary of the entire investigation is given below.

I. FEASIBILITY OF THE WATERWAY.

3. In the valley of the Des Plaines and upper Illinois Rivers, ex
lent foundations for locks are available; the lower Illinois ha
gentle slope, so that any reasonable depth can be obtained by dr
ing, and the present diversion of water from Lake Michigan thro
the Chicago Drainage Canal is more than sufficient for naviga
purposes. It is therefore the opinion of the special board that
waterway from Lockport to the mouth of the Illinois River is feas

II. THE MOST ADVISABLE DEPTH AND DIMENSIONS FOR THE WATERW

4. In determining the most advisable depth for the waterway,
special board gives consideration to the character, origin, and dest
tion of the probable commerce, and the type and dimensions of
vessels best suited to handle the traffic. It states that if the wa
way is to be used by vessels capable of navigating the ocean and
Great Lakes, it should be given a depth suitable for the econo
carriers now used on those bodies of water, which would fix the d
at not less than 24 feet; but if it is to be constructed for ve
adapted to river traffic, navigation does not require its depth to ex
9 feet. A depth of 14 feet, which has been frequently urged for
waterway, is greater than necessary for river navigation and enti
insufficient for either lake or ocean vessels. A uniform depth on
Mississippi and its leading tributaries will be far more benefici
the navigation interests of the United States than a main chann
great depth with shallow feeders. As a channel of 8 feet depth is

aintained from Cairo to St. Louis, and can be extended from St. ouis to Utica, on the Illinois River, at relatively small cost, business ution dictates that a waterway of this depth be obtained and tested fore entering upon enormously expensive projects of questionable ility.

5. The special board considers a bottom width of 160 feet in canal d 200 feet in the open river above the mouth of the Illinois sufficient a channel of 8 or 9 feet available depth. For safety and ease of vigation, the channel should be excavated to 11 feet in rock cuts d canals, and the locks should be given 11 feet depth, 80 feet width, d 600 feet usable length. A waterway of these dimensions would ve a capacity exceeding 100,000,000 tons per annum.

III. COOPERATION WITH THE STATE OF ILLINOIS.

. A project has been presented by the State of Illinois which con- nplates the development of water power at four sites between ckport and Utica, and the improvement of navigation by the nstruction of five large locks, 80 by 900 feet in horizontal dimen- ns, with 24 feet depth on their miter sills. This project proposes utilization for power purposes of the water which may flow ough the Chicago Drainage Canal and contemplates an ultimate nnel depth of 24 feet for navigation purposes, though the esti- tes, amounting to approximately $20,000,000, provide for 24 feet y to Brandon Bridge and for 14 feet below. The special board tes that the waterway proposed is more than sufficient for any bable navigation. It believes that the General Government will y cooperate with the State in a waterway from Lockport to the uth of the Illinois River if it assumes charge of the State structures Henry and Copperas Creek, and enlarges the existing channel in Illinois River below Utica to suitable dimensions.

CONDITIONS NECESSARY IN CONNECTION WITH COOPERATION TO FULLY PROTECT THE INTERESTS OF THE UNITED STATES.

. The special board states that a primary condition of any coöp- tion between the United States and the State of Illinois should the acceptance in perpetuity of full responsibility by the State of nois or its agencies for all damages by changes in lake levels, luding cost of compensating works, and for all damages to riparian ners, and the State should transfer to the United States the locks l the control of the new waterway thus created so far as needed navigation, and the locks and dams at Henry and Copperas Creek the Illinois River. With such a transfer the obligations of the te of Illinois to the United States with reference to the main- ance of the Illinois and Michigan Canal may be considered as quately fulfilled, and any equities of the United States in the its of way and other properties of this canal should be transferred the United States to the State of Illinois. The special board eves that should the State of Illinois be unable to complete the s suggested by the board or the bridges required by navigation, United States might then properly undertake to complete these ts of the project.

V. PLANS AND ESTIMATES OF THE COST OF WORK RECOMMENDED BE DONE BY THE UNITED STATES.

8. The existing Federal project for the improvement of the Illino River, adopted in 1880, together with the existing State projec provides for a 7-foot slackwater navigation from Utica to its mout which has already been obtained by dredging and by the constru tion of four dams, with locks 350 feet long and 75 feet wide. T opening of the Chicago Drainage Canal in 1900, however, added increased volume of water, which has raised the level of low wat so that 8 feet can be carried to Grafton, provided the upper mit sills at Henry and Copperas Creek are lowered about 1 foot, t crests of the dams are restored at the heights to which they we originally constructed, and portions of the pools deepened slight by dredging. The estimate of cost is as follows:

Excavation in pools and in river below Kampsville	$887,
Lowering miter sills and reconstructing gates	60,
Restoring crest of Kampsville Dam	7,
Miscellaneous and contingencies, 10 per cent	95,
Total	1,050,

The estimate for the 9-foot waterway, which ultimately may required, with new locks 80 by 600 feet, is $4,005,000. The annu cost of maintenance is estimated at $115,000 for the 8-foot waterw and $141,000 for the 9-foot waterway. An estimate of $3,710,000 also submitted for open-river improvement in the Mississippi River provide a depth of 8 feet between the mouth of the Illinois River a St. Louis, the estimate for maintenance being $125,000 annual After the 8-foot channel has been provided, a depth of 9 feet can obtained by dredging between these points, with an additional annu expenditure of $75,000.

VI. SUCH MEASURES AS MAY BE REQUIRED TO PROPERLY PRESER THE LEVELS OF THE GREAT LAKES, ETC.

9. The investigations and studies of the special board show t the diversion of water from the Lakes lowers the levels progressiv in proportion to the amount so diverted, the full effect not bei observable for some time; and that for the 10,000 second-feet divert through the Chicago Drainage Canal, at mean lake level, the wa surface will be lowered in Lakes Huron and Michigan 0.465 foot; Lake Erie, 0.448 foot; in Lake Ontario, 0.431 foot. Such lower would materially affect the carrying capacity of the large frei vessels, estimated at 88 tons per inch of draft, and would cause a l on American vessels alone at the lowest estimate of $1,000,000 annum.

10. Three methods for compensating for such diversion have b considered by the special board: (1) By the construction of s merged weirs with arbitrarily controllable sluices at the lower ends the Lakes; (2) by reducing the area of the natural outlets by construction of fixed contraction works therein; (3) by dredg harbors and connecting channels. The investigations of the bo show with certainty that the result of diversion of water throug new outlet is a lowering of Lake levels. The effect of the great stor

pacity of the lakes and of the natural fluctuations of level due to tural causes, such as the varying amount of rainfall and the varyg amount and direction of wind pressures, is such that the absolute vel at a given time at any given place can not be predicted, and man wisdom is inadequate to regulate a variation of discharge rough the outlet in such a manner as to produce a definite desired sult. Method No. 1 therefore must be classed as impracticable. mpensation by dredging is practicable, but on account of the tensive areas involved, this method would be unduly costly. Of e three methods, the second only is therefore favorably considered. e special board proposes to hold up the level of Lake Erie by the nstruction of three submerged weirs in Niagara River, at an estiated cost of $150,000, and that of Lakes Michigan and Huron by bmerged weirs in St. Clair River, at an estimated cost of $325,000, e total for compensating works being $475,000, with $15,000 nually for maintenance.

I. THE INFLUENCE ON VOLUME AND HEIGHT OF WATERS IN THE MISSISSIPPI RIVER BELOW CAIRO.

11. The influence on the volume of the Mississippi River due to y diversion from Lake Michigan will be an increase approximately ual to the amount of water diverted. The effect upon gauge height ll be small even at low stages, and at high stages it would scarcely appreciable and not of any importance.

I. THE EFFECT UPON THE CLIMATE OF THE LAKE STATES BY A CHANGE IN THE NATURAL CURRENTS OF LAKE MICHIGAN.

12. After extensive investigation and discussion of this subject the nclusion is reached that the effect on the climate of the Lake States, used by the diversion of 10,000 second-feet of water through the icago Drainage Canal, whether beneficial or injurious, would be so all that it could not be measured by the most delicate instruments.

. UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTH OF THE ILLINOIS RIVER AND THE MOUTH OF THE OHIO RIVER BY THE CONSTRUCTION OF A DAM AT OR NEAR JEFFERSON BARRACKS AND A DAM AT OR NEAR COMMERCE, AND THE DEVELOPMENT OF WATER POWER INCIDENTALLY CREATED BY SUCH DAMS.

13. The construction of such dams is not necessary for the execun of existing projects for the Illinois and Mississippi Rivers or of e projects recommended in the partial report printed in House Docent No. 1374, Sixty-first Congress, third session The special board ports that the work would be enormously expensive and not justid by resulting benefits to commerce and navigation or by the returns m water-power development.

CONCLUSIONS.

14. After due consideration of the reports of the special board the ard of Engineers for Rivers and Harbors concurs in general with e views and conclusions expressed therein. With the information

now available, it is not prepared to indorse certain details of the d cussions in the appendixes and elsewhere pertaining to the regulati of the level of Lake Superior, the regulation of the day and night d charge at Niagara Falls, and the estimates of cost for the dams acro the Mississippi River. But inasmuch as this difference of opinion these points does not affect the final conclusions, the board believ that nothing would be gained at this time by pursuing its investig tion further. The board concurs fully with the general conclusio expressed by the special board in its final report, but differs slight from those given in its preceding report. In this connection atte tion is invited to the following statements made by the Board Engineers for Rivers and Harbors in its report of January 30, 191 printed in House Document No. 1374, Sixty-first Congress, thi session:

> It does not concur with the view of the special board that the United States shou assume that part, if any, of the cost that is in excess of $20,000,000 for constructi the portion of the waterway between Lockport and Utica. Moreover, it suggests t the amount of diversion to be permitted from Lake Michigan should be determin if practicable, before the project is undertaken.
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> * * * * * * *
>
> It is understood that the sanitary district of Chicago and the State expect to devel considerable water power on that portion of the waterway between Chicago and Uti As it is proposed that the navigable channel between these points shall be built wi out cost to the United States, it is believed that the General Government should linquish to these local agencies any rights that it may have in the power to be thus veloped. It does not appear that there is any question of water power, flood contr or other matter that can be coordinated with that portion of the work to be done the United States for the improvement of navigation, so as to lessen the cost and co pensate the Government for its expenditures made in the interest of navigation.
>
> In conclusion it is recommended that the work proposed by the special board the United States in the Illinois River be not undertaken until the Secretary of W has received satisfactory assurance from the State of Illinois that the State will bu that portion of the waterway from Lockport to Utica without cost to the United Stat and in accordance with plans to be approved by him; and, further, until the intere of the United States have been satisfactorily safeguarded as indicated by the spe board, viz, that the State of Illinois, or its agencies, shall assume entire responsibil in perpetuity for all damages by changes in lake levels incident to the work, incl ing cost of compensating works, and for all damages to riparian owners along the p posed waterway from Lake Michigan to the mouth of the Illinois River, and that State shall transfer to the United States the locks and the control of the new wa way thus created so far as needed for navigation, and the locks and dams at He and Copperas Creek on the Illinois River.

15. It is the distinct recommendation of the Board of Engine for Rivers and Harbors that the term "control of the new waterw thus created so far as needed for navigation" shall be interpreted include such control of the use of water for power purposes as sh be necessary to insure the conditions of flow required for navigati Further, the board believes that the total volume of water to be verted from the natural discharge channels of the Lakes should definitely fixed by Congress; that a project, with estimate of co for works necessary to compensate for such diversion should be p pared to the satisfaction of the Chief of Engineers and the Secreta of War; that before any diversion is made beyond that at pres existing, the State of Illinois shall transfer to the Secretary of W the funds necessary for such works as given by the approved e mate of cost; that the works shall be built by the United Sta with the funds so provided; and that the control and maintena of such works shall be in and at the cost of the United States.

16. As indicated above, the work proposed by the special board nvolves an original outlay by the United States of $1,050,000 for the llinois River and $3,710,000 for the Mississippi River, or a total of 4,760,000, and provides for a navigable channel depth of 8 feet rom Utica to St. Louis. The act ordering the investigation appro- riated $1,000,000 "for the construction of a waterway from Lock- ort, Ill., by way of the Des Plaines and Illinois Rivers to the mouth f said Illinois River," and provided that "until these plans and stimates have been submitted and a project adopted by Congress he appropriation of $1,000,000 herein made shall not be avail- ble for expenditure." If the project be adopted by Congress, his conditional appropriation should be made available for the nprovement as a whole, and subsequent appropriations should be iade with a view to completion of the work in four years. The oard of Engineers for Rivers and Harbors recommends the adoption f the project under the conditions stated above.

For the Board:

W. M. Black,
Colonel, Corps of Engineers,
Senior Member of the Board.

INAL REPORT BY A SPECIAL BOARD OF ENGINEERS ON WATERWAY FROM LOCKPORT, ILL., TO MOUTH OF ILLINOIS RIVER.

New York City, *August 15, 1913.*

rom: A Special Board of Engineers.
o: The Chief of Engineers, United States Army.
ibject: Report on waterway from Lockport, Ill., to the mouth of Illinois River, and on certain related subjects.

The board of Engineers appointed by the Secretary of War Sep- mber 8, 1910, in Special Orders, No. 43, Office of the Chief of Engi- ers, for the consideration of a waterway from Lockport, Ill., by ay of the Des Plaines and Illinois Rivers, to the mouth of the said linois River, in its reports of November 1, 1910, and January 23, 11, has discussed certain of the questions referred to it—namely: Feasibility of the waterway; II, the most advisable depths and mensions for the waterway; III, cooperation with the State of inois; IV, conditions necessary in connection with cooperation to lly protect the interests of the United States, and V, plans and timates of the cost of work recommended to be done by the United ates. Since the submission of the above reports nothing has devel- ed to require any changes in the statements and conclusions erein given. For convenience of reference these reports are tached hereto marked as Appendixes E and F.

The necessary additional investigations having been completed, the sults of which are shown in Appendixes A, B, C, and D, the board w has the honor to submit the following report upon the remaining estions submitted to it for consideration:

> I. Such measures as may be required to properly preserve the levels of the Great kes and to compensate, so far as practicable, for the diminished level in said lakes l the connecting waters thereof by reason of any diversion of water from Lake chigan for the maintenance of the proposed waterway * * * or for any other pose.

This subject is specially discussed in Appendix A.

Since 1895 the United States Lake Survey, under the direction the Chief of Engineers, has made a systematic series of measuremen of discharges in the St. Marys, St. Clair, Detroit, Niagara, and S Lawrence Rivers, to determine the relation which exists between th volumes of water discharged by these rivers and the levels of the lak surfaces. These discharge measurements have been numerous an demonstrate conclusively that there is a direct connection between th height of each lake and the volume of water discharged at its outle

For a change of 1 foot from the mean of the stages covered by th observations on each lake the discharge will vary as stated in Table and conversely the changes of level in feet, due to diversions from th natural outlets of varying amounts, will be as shown in Table II.

TABLE I.

Lake.	Mean stage.[1]	Discharge at mean stage.	Change in discharge due to 1 foot change in level close mean stage.
	Feet.	*Second-feet.*	*Second-feet.*
Superior	601.80	75,000	15,300 gauge at S. W. canal pier.
Michigan-Huron	580.38	192,300	21,500 Fort Gratiot gauge. Lake St. Clair normal.
Erie	571.96	195,500	22,300 Buffalo L. H. gauge.
Ontario	244.60	230,000	23,200 Ogdensburg gauge. Discharge adjusted for effec closure of Gut Channel in Galops Rapids, estimate reduce existing discharges 9,000 cubic feet per sec below those formerly existing at the same stages.

[1] Mean of range during discharge measurements.

TABLE II.—*Changes of level, in feet, due to direct diversion of amounts varying betw 1,000 and 14,000 cubic feet per second.*

1,000 cubic feet.	Superior.	Michigan and Huron.	Erie.	Ontario.
	Foot.	*Foot.*	*Foot.*	*Foot.*
1	0.065	0.046	0.045	0.043
2	.131	.093	.090	.086
3	.196	.139	.134	.129
4	.261	.186	.179	.172
5	.327	.232	.224	.2165
6	.392	.279	.269	.260
7	.457	.325	.314	.303
8	.523	.373	.359	.346
9	.588	.419	.404	.399
10	.654	.465	.448	.431
11	.719	.511	.493	.474
12	.784	.558	.538	.517
13	.850	.602	.583	.560
14	.915	.659	.628	.603

These changes are obscured by variations in the supply of wa from rains, by evaporation, by the effects of winds, and by obstruction of the outlets by ice, and due to the reservoir capac of the different lakes the action will not be immediate. As shown the report of the Lake Survey for 1904, page 4120, one-half of ultimate fall of Lakes Michigan and Huron will occur in 1.46 ye and nine-tenths of the fall will be completed in 4.86 years. For L Erie 50 per cent of the ultimate lowering will occur in 2.5 mon and 90 per cent in 8 months; for Lake Ontario, in 2.1 months an months, respectively.

It is therefore evident that when the Lakes stand at mean lake vel a diversion of 10,000 cubic feet per second from Lake Michigan rough the Chicago Drainage Canal will ultimately produce a lower- g of the water surface of Lakes Michigan and Huron and its connect- g harbors and channels of 0.465 feet (5.58 inches), of Lake Erie of 448 feet (5.38 inches), and of Lake Ontario of 0.431 feet (5.16 inches); lower stages the effect will be greater, due to the relatively smaller ea of the cross section of the outlets.

The largest lake freighters recently built carry over 80 short tons of eight for each inch of loaded draft, and an uncompensated Chicago version of 10,000 second-feet would cause a loss to each vessel of at ast 446 tons in carrying capacity for each down trip through the annels connecting with Lakes Michigan and Huron. This, based on 25 trips per season, with vessels returning light, means a loss at least 11,150 tons per year, and at a freight rate of 55 cents r ton represents a monetary loss of at least $6,000 per large vessel r year. During the season of 1912 there passed through the locks Sault Ste. Marie over 72,000,000 tons of freight, the greater part which was carried in vessels of such size as to be affected by any s of depth caused by a Chicago diversion. The tonnage of 1913 ds fair to exceed the tonnage of 1912. The lowest estimate of the s to American vessels alone that has been brought to the attention the board is over $1,000,000 per annum, and the loss will increase th the increase in the number and size of vessels.

It is evident therefore that any diversion with consequent lower- g of lake levels will cause a direct financial loss to vessel owners d such a loss can be prevented only by the adoption of remedial easures. For this purpose three methods have been proposed. st, to regulate the level of the Lakes between fixed limits by the nstruction of submerged weirs and adjustable sluices at the lower ds of the Lakes, and by this means not only to prevent the oscilla- ns of lake levels which occur daily each season, but also to equalize flow over a series of years. Second, to compensate for the dimin- ed discharge by reducing the area of the natural outlets by con- uction of contraction works therein. Third, to restore the original pths of the harbors and connecting channels by dredging.

t is the opinion of the board that while it is feasible to raise the erage surface of the Lakes to any desired elevation by means of irs and sluices it will be exceedingly difficult and in many ways practicable to regulate the oscillations of the Lakes to a greater ent than nature now does automatically. These oscillations se from winds, from the relative amount of rainfall and evapo- ion, and from other natural causes, which man can neither con- l nor foresee. The effect of any attempted regulation will be al rather than general, and the local benefits will be offset by uries elsewhere. The difficulties in regulating lake levels are ly discussed by the International Waterways Commission in use Document No. 779, Sixty-first Congress, second session, and a umé of the views expressed therein is given in Appendix A.

o restore the diminished levels in the Lakes by constructing con- cting works in their outlets does not however present any serious ficulties. A careful discussion of the proper locations and dimen- ns of such works is also given in Appendix A.

At the foot of Lake Ontario the closure of the Gut channel of th Galops Rapids by the Canadian Government has had the effect c raising the level of Lake Ontario an amount nearly equal to th computed lowering of the lake by a diversion of 10,000 second fee at Chicago, and no compensation is at present deemed necessary t restore former conditions in this lake.

In Appendix A it is proposed to diminish the outflow of Lake Eri by the construction of three *submerged weirs in Niagara River* in th vicinity of Squaw Island, which would average about 4.2 feet i height and would contain about 15,000 cubic yards of masonry. Th estimated cost is $150,000.

To raise the level of Lakes Michigan and Huron *submerged wei* are proposed *in St. Clair River*, covering 3 miles of river below th mouth of Black River at Port Huron. The weirs as suggested i Appendix A have a height of from 5 to 6 feet above the river be contain about 65,000 cubic yards of material, and their estimate cost is $325,000. It is computed that these weirs will increase th velocity of the water flowing over them slightly (from a mean of 3.2 feet to 3.89 feet per second), but, on the other hand, above the mout of Black River the river slopes and velocities which are now excessi will be diminished, and navigation on the whole will be considerab benefited.

The Chicago diversion has no effect on Lake Superior.

Compensation for the loss of elevation on Lakes Michigan, Huro and Erie, and their connecting waters, due to an assumed diversi from Lake Michigan of 10,000 second-feet, will by the plan abo outlined involve an expenditure of about $475,000, to which shou be added an amount for the maintenance of the weirs, estimated about $15,000 per year, the total cost being much less than the cost restoration of depths by dredging. It is the opinion of the boa that while other plans have been proposed, compensation by fix contraction works similar in general to those above described affor the cheapest and most satisfactory method of preserving the lev of the Great Lakes.

No estimates have been considered for compensating for the loss depths in the St. Lawrence River, as such work is regarded as outsi the scope of the duties of the board.

VII. The influence on volume and height of waters in the Mississippi River bel Cairo.

This subject is specially discussed in Appendix B.

The influence on the volume of the Mississippi River due to a diversion from Lake Michigan will be an increase approximat equal to the amount of the diversion, since the losses due to eva oration and other causes will not be large, and at extreme hi water the increase, due to a 5,000 second-foot diversion, will be l than one-third of 1 per cent from Cairo to the mouth of the river.

Except as increase in volume results in increase of gauge heig or depth of water available for purposes of navigation, it will be no importance within any limits of diversion heretofore conside as permissible.

The effect of any diversion upon gauge height will always small, and at the highest stages practically nothing, but the ex effect at any time or at any stage can not be determined, since t ffect will be complicated or obscured by various other changes in he regimen of the river.

An extended series of discharge observations of the Mississippi iver was taken under the direction of the Mississippi River Comission from 1879 to 1885, at Columbus, Ky., below the mouth of he Ohio River; at Helena, Ark., below the mouth of the St. Francis iver; at Arkansas City, Ark., at Wilsons Point, Miss., and at ays Landing, below the mouths of the White and Arkansas Rivers; t Warrenton, Miss., below the mouth of the Yazoo River; at Red iver Landing and at Carrollton, La. Mean discharge curves have een derived from these observations, and extended and checked by umerous observations made at later dates.

On plate 1 of Appendix B are shown the mean discharge curves at olumbus, Ky., Helena, Ark., Vicksburg (and Warrenton), Miss., nd Red River Landing, La., and the curves of theoretical increase gauge heights deduced from them. These curves show that the fluence of a given diversion from Lake Michigan through the hicago Drainage Canal upon the volume and height of the Missisppi River varies with the localities and at the same locality with ery change in discharge and that in all cases the increase in gauge ights will be small.

Assuming that increase in gauge height will not be accompanied changes in cross section of the river or that its effect will not be herwise obscured, the diagram indicates that at all four places nsidered it would require an increase in discharge considerably ceeding 10,000 cubic feet per second to increase the gauge heights 1 foot even at the lowest stages of the river; under similar assumpon at stages corresponding to 40 feet at Columbus the curves dicate that it would require an increase of over 50,000 cubic feet r second to increase the gauge height 1 foot at Columbus, Helena, d Red River Landing, or over 5,000 cubic feet per second to fect the gauge height one-tenth of a foot. At higher stages the ect would be even less and it is evident that on extreme flood ights the effect of any permissible diversion would be trifling and ould have no important bearing upon the heights of levees or her works designed to afford protection against floods.

But even these small increases of gauge heights are not an exact easure of the increase in depths which would result from an increase the volume of the river. As the discharge increases, not only es the surface of the water rise, but that of the bars also. This bject was discussed by a former board, and it was shown by an tended series of observations that a rise of the river of 1 foot is companied by a rise of bar of not less than 6 inches. The rise of e bar occurs more slowly than the rise of the water surface, and as e river is continually fluctuating the full effect does not appear in e observations. Where a permanent addition is made to the disarge, the rise of the bar may more closely approach that of the ter surface, but in any case the influence of the increase in disarge on navigable depths will be insignificant.

The board has also shown in discussing the sixth subject that the ect of diverting 10,000 second-feet through the Chicago Drainage nal from the Great Lakes will appreciably injure their navigability, d in its preceding report that such a diversion was not necessary obtain either the 8 or 9 foot navigation recommended from Chicago to the mouth of the Illinois River. Since its last report it has bee in conference with the authorities of the State of Illinois in referen to the advisability of removing the existing dams in the Illino River. Even with the diversion of not more than 4,167 second-fe at present authorized, the board agrees with the State authorit that the dams could be removed and the desired channel dept obtained by dredging alone; but the project for obtaining channe of 8 and 9 feet depth, recommended by the board in the report January 23, 1911, contemplates the fullest possible use of the wo already done on the Illinois River, which has been improved to depth of 7 feet. To remove the locks and dams, and thereaft obtain depths of 8 and 9 feet by dredging alone, will add greatly the cost of the improvement.

If large amounts of water are to be admitted into the river, t removal of dams would reduce the damage to the valley from ove flow from this discharge; but the board reiterates that a diversi exceeding 1,000 second-feet is not necessary for navigation purpos alone in the Illinois River, and that an added discharge will produ a slight and inadequate effect on the Mississippi River.

The object of diverting 10,000 or more second-feet from La Michigan is not primarily to benefit navigation, but to dilute sewa and to create power, and the United States should not be burden with the cost of protecting the lowlands of the Illinois Valley fro overflow where such diversion and overflow are unnecessary f navigation alone.

VIII. The effect on the climate of the Lake States by a change in the natu currents of Lake Michigan.

This subject is specially discussed in Appendix C.

While the variations of the levels of the Great Lakes have be carefully studied for a long period on account of their effect on t depths of harbors and connecting channels, it is only during rece years that data have been collected relating to their temperature a currents. The information thus obtained is not only incomplete, b the conclusions derived therefrom by some observers are contrad tory. To properly investigate the subject, the board has theref found it necessary to make a series of independent observations. report on the results of these investigations is given in Appendix

It has been quite generally believed that there exists in La Michigan a surface current flowing in a southerly direction along t Wisconsin shore and northerly along the State of Michigan, and th it is quite fixed in direction, particularly during the summer mont but the observations conclusively show that this belief is a popular f lacy, and that the surface currents, instead of being fixed in directi are extremely variable. They tend to follow straight lines, depen ent on the direction of the winds and other conditions. With a wi blowing from a northerly direction, there is a tendency for a southe surface flow of water on both the Wisconsin and Michigan shor and when the wind blows from a southerly quadrant the currents both shores tend to flow to the north. A westerly wind raises t water on the Michigan shore, and an easterly wind on the Wiscon shore. Changes of level and of currents are also frequently p duced by variations in barometric pressure.

The observations also show that the temperature of the surface ater at any locality is affected by the direction of the wind. Dur- g the summer months at any locality where the wind is blowing n-shore the surface water is warmer than on the opposite side of e lake, and a change to an offshore breeze will frequently reduce e temperature of the surface water at this locality from 10 to 15 grees. This phenomenon is accounted for by the fact that the ind raises the water on the shore toward which it blows and de- esses it on the opposite shore. Due to this disturbance of the uilibrium, there is a return flow, which does not occur on the sur- ce, but at a considerable distance below it. Instead of being in a utherly direction on one side of the lake and a northerly on the her, the path described by the waters is, on the surface, in the rection of the winds, and thence on the leeward shore, the current i directed toward the bottom of the lake, whence it flows at a great pth back to the windward side and finally up to the surface, thus mpleting the cycle.

While the temperature of the surface waters of the lakes varies om 32° F. during the winter months to nearly 80° in summer, the riations at 100 feet below the surface are within much narrower mits. In Lake Superior the temperature of the water at great pths appears to remain at approximately 39° during the entire ar and on the other Great Lakes, at depths of 100 feet, does not ceed 50° F. during the warmest weather.

The return subsurface currents are continually bringing the lower ters to the surface and affecting its temperature, making it cooler summer and warmer in winter. They also retard the formation of e, as they render it necessary to reduce a large volume of water proximately to the freezing point before it congeals.

The effect of water on the temperature of the air passing over it a function of the strength of the winds and the area and depth of e lake. Lake Michigan has an area of over 22,000 square miles. greatest length is 307 miles, its width 118 miles, and its maximum pth 870 feet. It exposes an enormous water surface to the action winds, and its depth gives an immense volume to absorb or radiate at. Moreover, it is connected to Lake Huron, which also has an ea exceeding 22,000 square miles and a maximum depth of 750 t, by a broad and deep channel, through which not infrequently ere is a flow of over 2,000,000 cubic feet per second, and any mate- l change of temperature in one lake will be transmitted to the er.

These, rather than lake currents, are the principal factors which ect the climate of the Lake States, and the diversion of any water ough the Chicago Drainage Canal will primarily affect the climate y to the extent that it reduces the area or volume of the lake. has been previously stated, the diversion of 10,000 second-feet will imately lower the level of the lake 5.58 inches. The reduction in ume or area of a lake 870 feet deep and having an area of 22,000 uare miles, by a reduction in depth of this amount is inappreciable. t may therefore be stated that the effect on the climate of the Lake tes, caused by diverting 10,000 second-feet of water through the icago Drainage Canal, whether theoretically beneficial or injurious, would be so small that it could not be measured by the most delica instruments.

IX. Upon the improvement of the Mississippi between the mouth of the Illin River and the mouth of the Ohio River by the construction of a dam at or near Jeff son Barracks and a dam at or near Commerce and the development of water pow incidentally created by such dams.

This question is specially discussed in Appendix D.

The existing projects for improving the navigation of the Mississip River contemplate a channel 6 feet deep at low water from t mouth of the Illinois to St. Louis, and 8 feet deep from St. Louis the mouth of the Ohio. These depths are ample for all existi river navigation. To provide for a reasonably prospective co merce this board, in its report dated January 23, 1911, House Doc ment No. 1374, Sixty-first Congress, third session, recommends th an 8-foot channel be made from St. Louis up the Illinois River, th affording a depth of 8 feet from the upper Illinois to the mouth the Ohio, and that, should an increasing traffic demonstrate t necessity for additional facilities, a channel 9 feet deep be mac A depth of 8 or 9 feet, properly utilized, is sufficient for an enormo traffic.

The construction of the two dams referred to in the portion of t act of June 25, 1910, quoted above, is not necessary to create dept of 8 or 9 feet. The desired improvement may be made at a mu less cost, by the simpler methods of regulation and dredging.

The board is aware that a channel depth greater than 8 or 9 f has been considered by some as desirable, and that a low-wa channel depth of 14 feet or more has been advocated. Methods obtaining a depth of 14 feet have been considered by a former boa whose report, published in House Document No. 50, Sixty-fi Congress, first session, shows that even for this greater depth method of regulation and dredging is preferable.

The present board concurs in the conclusions of the former boa and is of the opinion that the construction of high dams is not better method for securing such greater depth of channel, ev should the latter ever become necessary, and that only an extrem low cost of the water power incidentally created by such dams possibly warrant their construction.

To determine the best location for the upper one of the da described in the act, a survey was made at the request of the bo by the United States Engineer office at St. Louis to ascertain depth of the rock at sites regarded as most advantageous. Th rock borings are described in Appendix D. For the lower or Co merce dam the board uses the information procured by a form board, whose report is published as House Document No. 50, Six first Congress, first session.

The least objectionable site for the St. Louis dam is at the foot Stein Street, where rock occurs within the low-water bed of river at a general depth of about 77 feet, as shown in plate 1, App dix D. East of the low-water bed some of the borings showed rock to be at depths of over 119 feet below low water. (See plat Appendix D.)

The site selected near Commerce is at Grays Point, near mile 1 below St. Louis, where, although the soundings show the rock of river bed to range between 24 and 85 feet below low water, it is p ble to found most of the dam on rock at the higher elevation. cordingly, the difficulties of construction would be somewhat ss than at the site of the proposed St. Louis dam.

In the discussion of the construction of these two dams, it seems sirable first to consider fully the details of the only plan that has, far as we know, been seriously advocated. This is the plan of the nsulting engineer of the Lakes to the Gulf Deep Waterway Asso- tion, which is quite fully described in Appendix D and in the papers companying the latter.

Briefly, this plan contemplates the construction of two dams, the per one near St. Louis with crest at elevation 413, Memphis datum, lower one near Commerce with crest at elevation 343, the dams be substantially similar, each with 3,000 feet of fixed spillway in form of "an equilateral slant" with vertex upstream and with bear-trap section" at right angles to the stream 1,000 feet long, th a range of 15 to 16 feet below fixed weir level. Each dam is ured to pass the bank-full discharge with a depth of 10 feet on crest "and greater floods within desirable limits." Bank-full ge at St. Louis is about 30 feet above low water. The flood of 3, which did an enormous amount of damage at East St. Louis, s, at its maximum, 38 feet above low water, and the greatest orded flood, that of 1844, 41.4 feet above low water.

This plan of the Lakes to the Gulf Deep Waterway Association poses the development of power at St. Louis at all stages below bank-full stage, and as greater floods are to be passed through dam by means of bear-trap gates, the dam will at those higher ges create practically no head, and during such stages the power fail. In 1883 the river was above the bank-full stage for 17 secutive days, in 1892 for 36 consecutive days and again for 12 secutive days, and in 1903 for 16 consecutive days. As a power position the proposed dam, without an auxiliary steam plant, is lently not sufficiently trustworthy from a business point of view. angements based upon the expectation of constantly securing ver at anything like the maximum rate would eventually prove ppointing; while a steam auxiliary would necessarily have to be capacity equal to the maximum estimated output of the pro- ed water power.

he effect of the proposed St. Louis dam upon flood elevations its serious consideration. At the St. Louis site there are no falls apids such as generally suggest the feasibility of power develop- t and permit the work to be done with relatively little or no nges of river stages. On the contrary, the general slope of the r near St. Louis is about six-tenths of a foot per mile, and as the -water elevation at the St. Louis site is 385.6, a dam whose crest 413 would concentrate at this locality the fall of about 46 miles ver. With banks which, even now, are submerged during floods, readily apparent that, while the raising of the level of the water ace in the pool above the dam might be permissible during low er, the effect during floods would be disastrous.

he Mississippi River in the vicinity of St. Louis has been exten- ly contracted by bridges and by works to improve the low-water nnel and by levees constructed on reclaimed land. This con- tion has already produced a dangerous increase in flood heights.

In as thickly settled a country as surrounds St. Louis, a furth increase in flood heights in the present contracted section, such might be produced by a high dam, can not be permitted.

In House Document No. 772, Fifty-ninth Congress, first sessio the Board of Engineers for Rivers and Harbors invites attention the fact that the effect of confining a flood such as that of 1844 in channel 2,000 feet wide will require a mean velocity of 14 feet p second for the maximum discharge, estimated at 1,360,000 cul feet per second, to pass through the present channel at the Ea Bridge with the water surface at an elevation of 45 feet above t zero of the gauge (the grade proposed for levees now under constru tion). Even if the flood should cause a scour to bedrock, a distar of some 20 feet below the present river bottom, a mean velocity 8 feet would result. Either assumption appears less probable th a material further increase in flood heights.

It is our opinion that, before the power dam proposed by t Lakes to the Gulf Waterway Association could be permitted at t locality, the levee under construction around East St. Louis m be set back about 2,000 feet and all buildings and embankme which are in front of the new levee, not absolute necessities transportation and which interfere with the run-off of water, removed, or provision otherwise made for discharge of at le 400,000 second-feet more than at present provided for.

It is impracticable to set back the levees of East St. Louis 2, feet and to remove all structures between the levees and the ri It is equally out of the question, within reasonable limits of cost without obliterating the working head, to provide at the dam for excess flow of 400,000 cubic feet per second. Consequently the c struction of the dam under the plans advocated by the Lakes to Gulf Waterway Association would expose the people of the vicir to great disaster.

While power can be created at low heads, in view of the h probable cost of construction of the dam and power house, its nomical development at this locality appears to demand a low-w head of at least 25 feet. At Keokuk, where foundation conditi were most favorable and the cost of construction certainly far than it would be at St. Louis, a head of 40 feet was regarded as ne sary. The development of power in commercially available f requires a regulated output of alternating electrical current, to production of which a substantially uniform speed of revolutio the electric generators is essential. This uniformity of speed can be secured when there is little or no variation in the head of w on the turbines. Moderate reduction in the normal head redu the output of current while maintaining uniformity of speed. Gre reduction of head makes it impossible to maintain the required sp of revolution and then the output of alternating current ceases. extreme variation which is usually permitted occurs when the m mum head is 55 to 60 per cent of the maximum head, but by ap priate design the range may be extended, permitting the minin head to be 40 to 45 per cent of the maximum, accompanied, howe by a considerable loss of efficiency at the high heads which corresp to low water. In the case of the dam proposed by the Lakes to Gulf Deep Waterway Association, the design does not contemp development of power at stages above the bank-full stage. At d for some distance below the latter stage the head will be below the rmissible limits, so that considerable dredging below the dam will necessary in order to permit power to be developed even to this rtial and unsatisfactory degree. Considered alone upon the basis the power to be developed, the proposed dam is therefore not isfactory, and the dredging which is necessary to make it available to the bank-full stage will not only add greatly to the cost, but will o be attended with unusual difficulties.

As is well known, the Mississippi River at St. Louis carries large antities of sediment, most of which is derived from the Missouri ver. The amount discharged by the Missouri River during the ur 1879, a year of extremely low water, was estimated by the sident of the Missouri River Commission as about 400,000,000 bic yards. (See Annual Reports, Chief of Engineers, 1881, p. 1653, l 1887, p. 3090.) The quantity of sediment transported at any e varies with the velocity of the water. The velocity of the water wing through the pool which the dam would create above it would reduced at low water from about 2 feet per second (which at sent exists in the river) to about three-tenths of a foot, and at nk-full stage from about 7 feet to 4 feet. As long as the current vs without interruption material in suspension moves down the er with the same velocity as the water, but a checking of the cur-t will cause a deposit of immense amounts, deposits of from 20 to feet in depth having been formed in a single season behind the meable dikes constructed to improve the navigation of the river ow St. Louis.

Vhile no complete investigations have been made to determine the above such dams, the results are of record at two important dams, a high dam at Austin on the Colorado River of Texas, and the er a low dam for irrigation purposes at Laguna, on the Colorado er of southwestern United States. Above the dam constructed Austin, Tex., in 1893, there is reported by Prof. Thomas U. Taylor, he University of Texas, a deposit in the first four years after its struction of 31,667,000 cubic yards, or 38 per cent of its reservoir acity. In a paper presented to the American Society of Civil gineers, January 1, 1913, by Mr. H. T. Cory, a fill is reported above dam at Laguna, Ariz., in one season of 20,000 acre-feet (over 00,000 cubic yards). Some idea of the extent of the fill to be ected on the Mississippi may be obtained from the sediment ervations on the Missouri River near its mouth, taken at St. rles in 1879. These observations show that at a stage of about eet above low water, with a mean velocity of 6.7 feet per second a discharge of 257,000 second-feet 3,971,000 cubic yards of erial were carried downstream in suspension per day. When the city was reduced to 3 feet per second, the amount carried in sus-sion per day was only 65,000 cubic yards, the volume of discharge his velocity being 40,000 second-feet. A volume of 257,000 nd-feet at this reduced velocity would therefore carry about 000 cubic yards, and a deposit of 3,555,000 cubic yards per day dicated for this stage as a result of the construction of the dam. observations do not extend to the higher discharges, but assuming at a bank-full stage in the Mississippi River below St. Louis with a discharge of 600,000 second-feet the amount per cubic fo carried in suspension did not exceed that at a 20-foot stage in t Missouri River, a reduction of velocities to 4 feet per second wou cause a deposit of over 2,000,000 cubic yards per day for that stag The pool above the dam would therefore rapidly fill, and unless dred ing operations were undertaken on a scale never before attempt the bed of the river would rise, flood heights would increase, and t pool would soon cease to be of any value as a means of improvi navigation.

As a means of overcoming these difficulties, it has been suggest that the regimen of the river above the dam be radically changed increasing the depth and diminishing the width of the stream, so to secure velocities equal to those which obtain under existing c ditions. In a sewer or canal of regular section the correspondi problem admits of ready solution. In a river conditions vary fr section to section, and the true mean depth can at best be o approximately determined. The mean velocity of the Mississi River at this locality at low water is about 2 feet per second, wh requires for existing slopes and widths a mean depth of about 6 f The slopes would be reduced by the construction of the dam to ab one-half those at present existing, and to maintain the low-wa velocity unchanged would require that the mean depth be increa to about 12 feet.

To insure a uniform velocity of flow in the proposed channel tendency of the river to scour its bed and banks must be prevent otherwise the pool and bar formation that now obtains in the ri will be perpetuated. This renders necessary a complete regulat of the portion of the river affected.

It is, however, a mistake to assume that the excavation work co be left to be done gradually after first completing the dams. erection of the dams would cause a radical change in the regimen of river which, as shown above, would cause immense deposits un a reduction of the velocities could be at the same time prevent The channel excavation and regulation necessary for any adop channel depth must therefore be carried on rapidly and, so far possible, simultaneously with the creation of the pools. Every ye delay in the completion of the project would add enormously to original cost, by reason of these deposits and their removal. the 400,000,000 or more cubic yards of sediment flowing out of Missouri River annually, the amount deposited would, theref depend on the rapidity with which the channel was built; but ass ing that not more than 10 years were required to complete the char and that the deposit were only 100,000,000 cubic yards per year, increase in cost from this item alone would be not less t $100,000,000.

If abnormal accumulations of sediment, resulting from chang regimen due to the construction of the dam, must be remove they occur, and if the regulation works must be prosecuted tematically and continuously so that the average depth shall incr as the average slope above the dam is diminished by its progres construction, the problem of executing the dredging and building regulation works becomes one of extreme difficulty, since both op tions must be performed upon a scale not hitherto attempted.

lering the dredging alone, the dredged material must be com-
etely removed from the limits of the regulated channel and de-
sited well beyond the reach of floods, to avoid interference with
eir free discharge. For handling even 100,000,000 cubic yards
nually, the services of at least fifty 20-inch hydraulic dredges,
orking continuously throughout the year with double crews, would
required. To construct and operate these dredges would in itself
ove a formidable task. The regulation of the channel above the
m would present additional difficulties.

The proposed St. Louis Dam furthermore involves the complete
sure of a very large river, whose floods are exceeded in magnitude
few of the great rivers of the earth. To prevent disaster to the
rk and to the occupants of the valley below, the dam, power house,
d head bay walls must be built of masonry, founded on solid rock,
depths averaging about 77 feet below low water and 118 feet below
reme floods. Variations of stage whose frequency and extent are
strated by the accompanying hydrograph (see plate) and floods
as much as 1,300,000 cubic feet per second might occur during con-
uction work. Bridge piers have been built under such circum-
nces, but no dam has ever been attempted under conditions
proximating these in severity. At the Keokuk Dam, which has
t been completed, rock was everywhere found within 5 to 12 feet
he low-water surface, the extreme flood discharge for which pro-
on had to be made was only about 325,000 cubic feet per second,
h a height above low water of about 20 feet, and the site was other-
e naturally adapted to power-dam constructions, yet the work
difficult and expensive, requiring over two years to complete and
ting about $20,000,000. A detailed estimate of a project consid-
l by the board to be preferable to that proposed by the Lakes-to-
f Deep Water Association is given in Appendix D. This estimate
a comparison of the difficulties of the Keokuk and St. Louis sites
icate that the St. Louis Dam, power house, and locks alone would
over $58,000,000. Dredging of deposits and regulation above
below the dam would add at least $100,000,000.

has already been noted that to permit the generation of power
o a bank-full stage it is necessary to lower the pool below the dam
the removal of a quantity of material estimated by the Lakes to
f Deep Waterway Association at 100,000,000 cubic yards, but
puted by this board to be from 200,000,000 to over 750,000,000
ic yards, dependent upon the channel depths to be obtained.
ming the figure of 100,000,000 to be correct for the yardage of this
ial dredging and its cost to be $25,000,000, and adding the cost
nd damage and levee protection, amounting to over $8,000,000,
total for the St. Louis dam would be over $191,000,000. The
test quantity of continuous power which the dam could generate
ld be that of low water, at which time, assuming the low-water
arge, including present authorized diversions from Lake Michi-
as reaching a total of 40,000 second-feet, and the head as reach-
6 feet, the maximum output would not exceed 146,000 electrical
epower, and the cost per horsepower would be over $1,300, which
xceeds the cost at which water power can successfully compete
coal, even when the latter is much higher in price than it now
the vicinity of St. Louis. Moreover, although the conditions are

so unusual that it is impossible to submit a definite estimate of t
cost of maintaining the proposed improvement, it is the opinion
the board that the mere cost of the dredging necessary to mainta
the river channel in the unnatural condition contemplated by t
project would far exceed the cost of the coal necessary for a stea
plant capable of creating the same power as that of the dams.

The plan of the Lakes to the Gulf Deep Waterway Association
the dam near Commerce, which it is proposed should be similar
the St. Louis dam already discussed in detail, while not equally op
to objection because of increase in flood heights, is neverthel
objectionable because of the failure of power at stages above ban
full stage and because of excessive cost, which latter, including c
of all requisite contingent works, would be about the same as that
the St. Louis dam.

As the dams proposed by the Lakes to the Gulf Deep Waterw
Association would raise extreme floods 3 feet or more at St. Louis,
the power at both dams would fail above bank-full stage, as the c
of construction would far exceed the highest figure at which wa
power can successfully compete with steam power, and as the grea
depths which the dam would create are not needed for navigati
this plan is without justification.

The board has, however, made studies of other plans, with a v
to overcoming the objections above cited. Some of these stu
are fully described in Appendix D, in which it is shown that
suitable arrangement of the dams as to crest, elevation, and leng
and by dredging, it may be possible to avoid the danger of increa
flood heights at St. Louis, and of the failure of power at high sta
at both dams, yet, under the most favorable circumstances, the f
cost of dam construction, dredging, regulation, power installations,
other requisite contingent works would be more than $428,000,
for the two dams, while their continuous output would be not c
250,000 electrical horsepower, and therefore the final cost of deve
ment of power will be far too high to justify the undertaking.

The board accordingly reports that the improvement of the
sissippi River by high dams below St. Louis is without merit and
worthy of further consideration.

W. H. Bixby,
Brigadier General, U. S. Army, retired,
President of the Boar

C. McD. Townsend,
Colonel, Corps of Engineers, U. S. Arm

C. Keller,
Major, Corps of Engineers, U. S. Arm

J. B. Cavanaugh,
Major, Corps of Engineers, U. S. Arm

John Bogart,
Civil Enginee

[For report of the Board of Engineers for Rivers and Harbors
page 3.]

APPENDIX A.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., August 13, 1913.

rom: Maj. C. Keller, Corps of Engineers.
o: The President, Lakes to Gulf Waterway Board.
ubject: Report on preservation of and compensation for diminishing levels of Great Lakes, etc.

The following report upon "such measures as may be required to roperly preserve the levels of the Great Lakes and to compensate, so r as practicable, for the diminished level in said Lakes and the con- ecting waters thereof by reason of any diversion of water from Lake ichigan for the maintenance of the proposed waterway * * * for any other purpose" is now submitted:

1. It seems hardly necessary to prove that if unaccompanied by orks which will diminish the flow in the natural outlet, an artificial version caused by creating a new outlet for any body of water must wer its level below that which would have existed in the absence the artificial outlet and diversion, and that the amount of such wering will depend upon the size of the new outlet and the volume us diverted. Certainly the asserted lowering would hardly be uestioned were the diversion at Chicago of volume, for instance, ual to that of the natural dishcarge at Port Huron. Familiar amples in proof of this might readily be multiplied, but one will ffice: Consider the case of a trough or fountain basin which re- ives a constant supply of water and from which the waste flows rough a rectangular notch or cut in the rim, the maximum dis- arge capacity of the notch being slightly greater than the constant lume of water flowing into the trough or basin. As a result of the cess discharge capacity of the notch, the basin will never fill flush the rim, but will reach and maintain some level of equilibrium ghtly below the top, and the waste will then equal the constant pply. If now the size or cross section of the outlet is increased ther by widening the first notch or by adding another one elsewhere the rim, the volume of water outflowing will at once be increased d will then temporarily exceed the supply. The surface level of e basin will therefore fall until it is so low as once more to bring pply and waste into equilibrium. It is plain that the difference tween the new level of the basin and its former elevation is due to e additional notch and is dependent on its size or cross section. e same effects will follow even if the supply is variable, but it will course be more difficult to demonstrate them directly.

2. On an enormously enlarged scale each of the Great Lakes repro- uces these familiar conditions. The Lakes are large basins of water d formerly discharged through a single outlet. It is evident and s been definitely proven by gauge measurements that the volume scharged through any outlet varies with its size, increasing as the ea of the outlet is increased when the level of the basin rises, and minishing as the area of the outlet is reduced by a fall in the basin. e opening of the drainage canal at Chicago produced precisely the me effect on the Lakes as the second notch. It increased the total ea of the outlets, and if the water supply to Lake Michigan had been fixed quantity, under constant atmospheric and barometric con-

ditions, the lowering effect of this artificial outlet would have bee definite and might after a suitable interval of time have been rea directly from the gauges giving the elevation of the lake's surface.

3. But the amount of water supplied to each lake from its drainag basin and reaching its outlet varies from year to year with the quar tity of rainfall (including snow), with the evaporation depender upon the relative temperature of air and water and upon the prev lence or absence of wind, with the soil absorption dependent upo temperature, capillarity and dryness of the soil, and with other le important causes which affect the quantity of water and snow fallir within the drainage basin, its return to the air direct or through the sc and growing crops, and its delay by temporary storage within th soil. The surface levels of the Lakes vary correspondingly. In add tion to the variations in the quantity of water supplied to each lak complications are introduced by ice in the outlets, which may gorg and cause the lake above to maintain an abnormally high stage calendar years with late springs and by wind and barometric effect the latter two of which especially on Lake Erie sometimes cause larg fluctuations in monthly surface levels. Plate 1 shows in separa curves the annual mean levels of all the Lakes, these levels being t integrated results of all the influences above described. A glance these curves of annual levels will show their irregular rise and fa and the consequent difficulty of proving by direct evidence just wh and how much is the effect upon lake levels produced by the creatio of an artificial outlet, such as that at Chicago. It is further a we known fact that the levels of all the Great Lakes are subject to co siderable seasonal fluctuations, shown on plates 2, 3, 4, 5, and which show certain curves of monthly mean lake levels. General speaking, they are low in the early spring and late fall, and high duri 3 to 4 of the spring and summer months. Such seasonal fluctuatio are due to corresponding variations in the net supply of water to t various lakes, this net or availably supply being in general low duri the months of November, December, January, and February; hig due to precipitation and run-off, during March and April; moderate quantity during May and June; and thereafter again below the ave age. These differences in net supply are not immediately producti of corresponding changes in monthly levels which may and do lag much as 3 or 4 months behind the acting causes. The extreme ran of the monthly levels of the Great Lakes for the period 1860–1911, i clusive, has varied from 3.32 feet for Lake Superior to 5.54 feet f Lake Ontario, with maximum changes in a single period of 12 mont of from 2.58 feet on Lakes Huron and Michigan to 3.97 feet on La Ontario. High water does not occur at precisely the same time on the Lakes. Due to climatic causes, it is earlier for the lower lak (Ontario and Erie) than for those above, the average difference in ti between high water on Lake Ontario (May–June) and high water Lake Superior (August–September) being nearly 3 months, and the is a corresponding interval between low waters (December–March Ontario and February–April on Superior).

4. Thus while it is certain that the diversion of water through a artificial outlet can not raise the lake levels and must either delay a diminish the raising or hasten and increase the lowering of the lak involved, the proof of this conclusion must, because of the variatio in the elevations of the lake surfaces just described, be indire

eginning in 1895, over five years before any diversion took place
hrough the drainage canal, the United States lake survey, under the
irection of the Chief of Engineers, United States Army, began a sys-
ematic series of measurements of discharge in the St. Marys, St.
lair, Detroit, Niagara, and St. Lawrence Rivers to determine the
lation, if any, which exists between the volumes discharged by those
vers and the levels of the lake surfaces. In order to determine the
w connecting lake discharge and lake levels, the discharge observa-
ons have covered as wide a range of lake levels as possible. Up to
e present the surface elevations during the measurements have for
ake Ontario (Ogdensburg gauge) varied between 242.9 feet and 246.3
et above sea level; for Lake Erie (Buffalo gauge), between 570.0 and
3.92 feet; for Lake Huron (Fort Gratiot gauge), between 579.43 and
1.22 feet, and for Lake Superior (above Soo Locks), between 601.30
d 602.30 feet. The observations used for Lake Superior are those
September, 1909, at Sault Ste. Marie, which are the latest taken
this locality.

5. These discharge measurements have been numerous and the
nge of lake-surface heights has been sufficient to demonstrate con-
usively that there is a direct connection between the height of each
ke and the volume of water discharged at its outlet. The observa-
ons have been carefully made, so that it is possible to state with some
ecision how much the discharge of any one of the lakes is increased
a given rise in its surface or, conversely, how much the discharge
ll decrease for a corresponding fall. For a change of 1 foot from
mean of the stages covered by the observations on each lake the
charge will change as stated in Table I.

TABLE I.

Lake.	Mean stage.[1]	Discharge at mean stage.	Change in discharge due to 1 foot change in level close to mean stage.
rior	601.80	75,000	15,300, gauge at S. W. canal pier.
igan-Huron	580.38	192,300	21,500, Fort Gratiot gauge. Lake St. Clair normal.
	571.96	195,500	22,300, Buffalo L. H. gauge.
rio	244.60	230,000	23,200, Ogdensburg gauge. Discharge adjusted for effect of closure Gut Channel in Galops Rapids estimated to reduce existing discharges 9,000 cubic feet per second below those formerly existing at the same stage.

[1] Mean of range during discharge measurements.

A change in level of 1 foot at high stages is accompanied by a some-
at greater change in discharge than at lower stages, because at the
her stages a given change in level has a greater effect upon the
a of the outlet, but only the mean values given in the above table
used in this discussion. Thus it would appear that for each level
any of the lakes there is a corresponding discharge fixed and
ermined by that level, and that on the other hand when the dis-
rge is given the level of the corresponding lake is also fixed. With
efinite change of surface height there is a corresponding increase or
rease of flow, as shown in the preceding table. The fact that an
ficial increase in outflow, such as that due to the diversion at
cago, will lower the lake immediately concerned and all dependent
t for their supply, is a direct and necessary inference from the above

discharge measurements. Any such increase of discharge above tha
which is the natural result of an existing lake level will have the effec
of drawing upon the stored water available in the lake at a greate
rate than before. Hence the lake will fall more rapidly and furthe
than it would have done due to the natural discharge at the natura
outlet, and the level to which the lake will finally fall is that at whic
the discharge through the natural or main outlet equals the norm
discharge less the diversion. The total drop in the level of the lak
surface, due to the diversion, is then plainly that which is necessar
to make the total outlet area (the sum of the areas of the natural an
artificial outlets) correspond to the total available supply. Conversel
a reduction in outlet area causing a diminution in outflow will resu
in raising the level until the discharge area once more corresponds wi
the available supply. This is actually taking place on Lake Ontari
where the closure of the Gut Channel of the Galops Rapids h
apparently caused a rise in the surface of Lake Ontario of 0.39 fo
or more. Based upon the quantities given in Table I, the changes
level, in feet, due to direct diversions of amounts varying betwe
1,000 and 14,000 cubic feet per second, are shown in Table II.

TABLE 2.

1,000 cubic feet.	Superior.	Michigan and Huron.	Erie.	Ontario.
	Foot.	*Foot.*	*Foot.*	*Foot.*
1	0.065	0.046	0.045	0.043
2	.131	.093	.090	.086
3	.196	.139	.134	.129
4	.261	.186	.179	.172
5	.327	.232	.224	.2165
6	.392	.279	.269	.260
7	.457	.325	.314	.303
8	.523	.373	.359	.346
9	.588	.419	.404	.399
10	.654	.465	.448	.431
11	.719	.511	.493	.474
12	.784	.558	.538	.517
13	.850	.602	.583	.560
14	.915	.659	.628	.603

6. With the outlets free of ice at any instant the volume of wa
discharged from one of the lakes is a definite quantity fixed by
level of the lake. With a constant supply of water and const
evaporation there would then be no change in the elevation of
lake's surface, except such temporary changes as might be caused
winds and barometric disturbances. But the flow into each lake
as has been explained, constantly varying, and while the discha
from the lakes is also ever changing, so as in the long run to tend
counterbalance changes in supply, yet these adjustments of sup
and discharge are not simultaneous, and the surface levels of the la
are therefore constantly fluctuating, as is readily seen from the pla
attached.

7. These regular but uncontrollable changes in lake level mask
effect produced by an artificial diversion. Such diversion plainl
an increase of the natural discharge and therefore disturbs the gen
equilibrium between supply and discharge which in the long
exists. If at the time of this diversion the lakes are rising, it
reduce the rise; if they are falling, it will increase the fall; and the

effect of the diversion will unquestionably be a reduction of the level which would have existed. This diminution of level is simply that corresponding to the finally lessened outflow at the natural outlet, and its amount can be determined from Table 2.

8. The above diminution of level caused by a diversion of given volume will not be immediate. A considerable time will elapse before any large part of the ultimate lowering of any of the lakes will have aken place. The time required to produce the lowering due to an artificial diversion from any of the lakes will depend on its surface area, so that the smaller the lake the sooner a diversion of given volume will produce its corresponding effect. As shown in the report of he Lake Survey for 1904, page 4120, half of the ultimate fall of Lakes Michigan-Huron will occur in 1.46 years, and nine-tenths of the fall will be completed in 4.86 years, so that the effect of a diversion is low to appear, and, as stated, changes in precipitation and run-off may serve to obscure the effect. For each lake of the Great Lakes ystem the time required for 50 per cent and for 90 per cent of the ltimate lowering is shown in Table 3.

TABLE 3.

Lake.	Time required to produce 50 per cent of ultimate lowering.	Time required to produce 90 per cent of ultimate lowering.
uperior	14.4 months	47 months.
ichigan-Huron	18 months	58 months.
. Clair	46 hours, or 0.006 month	6.4 days, or 0.213 month.
rie	2.5 months	8 months.
ntario	2.1 months	7 months.

9. The lowering due to an artificial diversion is not, moreover, onfined to the single lake from which the diversion proceeds, but ke effects may be caused in the lakes and connecting channels above nd below. The diversion at Chicago, now under consideration, is idespread in its hurtful effects, Lake Superior, by reason of the fall f 20 feet between it and Michigan and Huron, being the only one not njured thereby, though it should be noted that injury is unquestionably done at all of the channel of the St. Marys River in the 49½ iles from the upper sills of the locks at Sault Ste. Marie down to ake Huron.

10. From plates 1 to 6, herewith, it will be seen that the annual vel of Lake Superior has been falling since 1905, during the six ears between 1905 and 1911 having dropped about 1.3 feet, corresponding to a loss of storage capacity of more than six months' total ischarge. Lakes Michigan, Huron, and Erie have been falling since 908. In the three years between 1908 and 1911 they have each ropped more than 1.3 feet, and Lake Ontario has dropped about 2.2 et in the same time. On all the four lower lakes the mean water urface for 1911 was at least 1.2 feet below the mean level of the past 2 years. Lakes Michigan and Huron were in March, 1911, at eleva- on 579.30, only 0.30 foot above their lowest recorded monthly stage nce 1860, and the lowest monthly stage in 1911 on Lake Erie, 571.04, as only 0.35 foot above the lowest recorded monthly mean for that ke. These low stages are accompanied by corresponding reductions the depths of the St. Marys, St. Clair, and Detroit Rivers, and the

harbors upon Lake Erie, and as the depths of these harbors and connecting channels limit the draft to which vessels may load, the result is a corresponding loss of productive capacity in the large lake fleet which is now designed and built to take advantage of every inch o depth available at these critical points. The largest lake freighters when nearly fully loaded carry over 80 tons of freight for each additional inch of draft. A diversion of 10,000 cubic feet per second from Lakes Michigan and Huron by the Chicago Drainage Canal will, as shown above, eventually reduce the average level of those lakes at least 0.465 foot, or 5.58 inches, and of Lake Erie 0.448 foot, or 5.38 inches the losses of depth along the St. Clair and Detroit Rivers being intermediate between these values. Consequently, in addition to th unavoidable losses caused by the reduction of lake levels due t natural causes, an uncompensated Chicago diversion of 10,000 second feet for each single down trip of such a vessel would cause a loss o about 446 tons of carrying capacity. An average of 25 trips pe season would mean a loss of at least 11,150 tons, which at 55 cents pe ton would during a busy season represent an annual loss of ove $6,000 for the down trips of each large vessel. Each season many vessels of such size as to be affected by any loss of depth caused by Chicago diversion pass through the locks at Sault Ste. Marie. Base upon the known characteristics and numbers of the lake fleet, it ha been estimated that the total annual loss due to a Chicago diversio of 10,000 second-feet might be over $1,000,000, and this woul increase with number and size of vessels. A diversion of 10,000 second feet at Chicago has not been authorized, but the diversion alread made has produced a proportionate loss in depth and revenue. T prevent this loss, remedial measures are necessary.

11. The Board of Engineers on "Deep Waterways between th Great Lakes and the Atlantic Tidewaters" in its report of June 3 1900, House Document No. 149, Fifty-sixth Congress, second sessio pages 273 to 293, presented a plan for the regulation of Lake Eri between fixed levels by the construction of submerged weirs aggre gating 2,900 feet in length, combined with 13 adjustable sluices each 80 feet wide, controlled by Stoney gates, these works to be buil at the foot of Lake Erie, just below Buffalo Harbor. The regulate level proposed was 574.7 feet above sea level, about a half foot belo extreme high water in Lake Erie, and it was stated that these work would hold the lakes within 0.6 foot of the adopted level, temporar violent fluctuations not considered. It was further stated that th result of such regulation would be to raise the lake surface about feet above its ordinary low-water elevation. Moreover, while th low-water level of Lake Erie would be raised about 3 feet, it was est mated that by backwater Lake St. Clair would be raised about feet and Lakes Michigan-Huron about 1 foot.

12. In House Document No. 779, Sixty-first Congress, second se sion, pages 10, 11, and 12, and pages 49, et seq., it is clearly show to be impossible to regulate Lake Erie within the limits proposed i House Document No. 149, owing primarily to its wide and lawle variation in supply and further to the lake's sudden and violen oscillations, which have amounted to as much as 2 feet in an hou and 8 feet in a day, the difference in levels between the two ends the lake in extreme cases having at times been as much as 15 fee

he views expressed in House Document No. 779 are summarized
s follows: The regulating works, situated as proposed, would tend
o aggravate ice jams at the head of the Niagara, which in turn might,
uring southwesterly storms, cause disastrous inundation of the
wer lying parts of Buffalo. Moreover, the ice gorges now occur-
ng at the Horseshoe Reef at the head of the Niagara River retard
he opening of the season of navigation at Buffalo, and an aggrava-
on of these gorges might serve to increase this delay, while the works
hemselves might under these conditions be difficult to maintain,
nd furthermore, even during the ice-free months, raising the level
f Lake Erie by 3 feet would increase the overflow damage caused at
uffalo by severe southwesterly storms. Floods from Buffalo Creek
ould also be more damaging, while low-lying lands along the entire
xtent of the shore line of Lake Erie would be permanently sub-
erged. Such regulation, accompanied as it would be by a change
the outflow of Lake Erie, would prove detrimental to depths in
ake Ontario and in the St. Lawrence River. Regulation of the
vel of Lake Erie between wider limits, even between 572 and 574.5,
oes not, in view of its disadvantages, appear to be desirable. Reg-
ation of the level of Lakes Michigan and Huron would, if feasible,
ove beneficial only on those lakes and in the lower St. Marys River,
nd would be detrimental to the lakes and rivers below. Due to the
tremely wide variations in supply, however, the regulation of Lakes
ichigan and Huron is not considered feasible. Moreover, the works
ecessary for regulation would probably cause a serious obstruction
navigation at the head of the St. Clair River.

13. In the Transactions of the American Society of Civil Engi-
ers, vol. 63, June, 1909, Mr. C. E. Grunsky, member American
ciety of Civil Engineers, proposes the use of Lake Superior as a
orage reservoir, regulating it at a high stage within narrow limits
th a view to delivering a large flow at low stages of Lakes Mich-
an and Huron, thereby neutralizing in part at least the harmful
ect of the Chicago diversion. Concerning this it may be said that the
vel of Lakes Michigan and Huron depends on the total quantity of
ter supplied to them and the area of their outlet, and that, unless
e or both of these are altered, it is impossible to cause any change
their mean level over a series of years. Since storage in Lake
perior can not increase the total supply to Lakes Michigan and
ron, its only effect will be to lower the latter lakes and those below
ile accumulation of water is going on in Lake Superior. When the
ored water is subsequently discharged at perhaps an abnormally
gh rate of flow, the surface of the lakes below may, for a relatively
ef period, be elevated above its natural height more than it had
eviously been depressed, but the duration of such increase will be
rrespondingly brief, and in the long run, the mean stage of the
kes will not be benefited. Storage in Lake Superior may also, at the
pense of an increase in its fluctuations, reduce the range of fluctua-
n of Lakes Michigan and Huron. Such a change will not compen-
e for the absolute loss of water caused by the Chicago diversion, and
l not benefit navigation. Vessels habitually load to the extreme
ift permitted by the minimum depth along their route, and re-
ction of the range of annual fluctuation of Lakes Michigan and
ron will, during the season of navigation, afford no greater average

depth in the lakes and channels below the locks at Sault Ste. Marie, while the increased fluctuations of depth in the St. Marys River and in Lake Superior may prove exceedingly damaging.

14. In House Document No. 779, Sixty-first Congress, second session, pages 56, 57, et seq., is a further discussion showing the impracticability of regulating Lake Superior between fixed limits and of using it as a storage reservoir to compensate for the loss of levels on th lower lakes due to the diversion at Chicago. Moreover, the mea level of Lake Superior for 1911 was 0.84 foot below its average o the 52 years, 1860–1911, and its outflow should now be restricte rather than increased, although the need for water below was neve greater.

15. Mr. F. C. Shenehon, member, American Society of Civil Engineers, has presented for the consideration of the board two plans, on for compensating, the other for regulating the levels of Lake Eri each of them involving the construction of certain works in th Niagara River.

16. The first plan, as set forth in his letter of October 12, 1912 with plates 8 and 9 attached hereto, proposes the construction immediately above the Falls of a submerged dam or weir across the Niagar River from Port Day to a point opposite it on the Canadian shor This weir would, it is asserted, raise the Chippewa-Grass Island Po about 6 inches, and, through back-water effects, raise Lake Erie abou 1 inch, with proportionate effects at intermediate points. In anothe place it has been estimated that a diversion of 20,000 second-fe from the Chippewa-Grass Island Pool will lower Lake Erie about inch. The existing diversion on the American side of the pool 15,100 second-feet, so that the proposed weir would compensate th level of Lake Erie for somewhat more than the lowering estimated result from the diversions of the American power companies Niagara Falls. At the same time the weir, located as proposed, mig considerably improve conditions of flow at both ends of the Hors shoe Falls. This plan, while probably of benefit in connection wi power and scenic conditions at Niagara Falls, does not, however, ful compensate for "diversion of waters from Lake Michigan," and whi it may have merit, the board does not deem it necessary to discuss further.

17. The second plan of Mr. Shenehon is for intermittent regulati of the level of Lake Erie by constructing, 1,000 feet below the Buffa waterworks intake pier and just above the International Bridge, adjustable weir about 480 feet in clear width, which, when complete closed, will diminish the outflow of Lake Erie by about 30,000 se ond-feet. Were the gates constantly closed, this would result raising the level of the lake somewhat less than 1.5 feet, but it proposed to operate this weir so that the flow shall be intermitte and to hold the level of Lake Erie during the navigation season little higher than elevation 573.

18. Largely in the interest of the power companies and of sce conditions at Niagara Falls, Mr. Shenehon proposes to keep the ga continuously closed during November and December and to remo them entirely during January, February, March, and April. Duri the months May to October, inclusive—that is, during the season navigation and of pleasant weather when visitors at Niagara Fa are most numerous—the gates are to be operated so as to red

e flow of the Niagara River to about 190,000 second-feet during
vening, night, and early morning hours—16 hours in all, and to in-
ease the flow to 220,000 second-feet during eight daylight hours.
uch an arrangement would, it is urged, improve scenic condi-
ons at Niagara Falls and would further help the power companies
etter to carry their peak loads without diminishing the daily flow
ver the Falls below its former natural volume.

19. The mean level of Lake Erie for the 52 years, 1860–1911, inclu-
ve, is 572.56. Were it possible to hold its mean level at 573 during
e months of navigation, the level of this lake would be raised about
lf a foot above its annual mean, and this would compensate Lake
rie for the lowering due to a diversion from Lake Michigan of over
,000 second-feet and by back-water effects would, it is believed, com-
nsate Lakes Michigan and Huron for a diversion at Chicago of about
250 second-feet. The benefits of this plan of regulation would be
eatest whenever the lake fell below its mean level, 572.56, and, at
wer natural stages of Lake Erie, such regulation might result in
mpensation on Lakes Michigan and Huron for a Chicago diversion of
rhaps 6,000 second-feet. Mr. Shenehon's proposal differs in detail,
t not in principle, from that proposed by the Board of Engineers on
Deep waterways between the Great Lakes and the Atlantic tide
ters," in House Document No. 149, Fifty-sixth Congress, second
ssion, which is discussed in paragraphs 11 and 12 of this appendix.
e objections to this plan are those which apply to any scheme for
gulating the lakes—i. e., to substituting controlled and artificial
vels and fluctuations of levels for those which now exist. It is not
lieved that any scheme of regulation has sufficient advantage over
e plan of compensation by means of contraction works in the out-
s to justify its adoption. The contraction works permit the nat-
al oscillations to continue undisturbed and cause no vital change
stages and in oscillations of the lakes below. Moreover, under
. Shenehon's plan the extent of compensation on Lakes Erie and
chigan-Huron will vary with natural conditions, compensation on
kes Michigan and Huron at times being sufficient for a Chicago diver-
n of perhaps 6,000 second-feet; at other times for a diversion of
rhaps less than 3,000 second-feet, with similar variations on Lake
ie. For full compensation on Lakes Michigan and Huron, for diver-
n greater than about 6,000 second-feet, supplementary works in the
Clair River would probably be necessary. Contraction works, on
e other hand, operate automatically and fully compensate for the
tual diversions. Further objections to this plan of regulation are
e deleterious effect upon Lake Ontario and the St. Lawrence River,
e to prolonged storage in Lake Erie, and there is also a possibility
at a succession of years of low precipitation might render the plan
olly inoperative. Mr. Shenehon's letter of October 29, 1912, with
te 10 attached, appended hereto, fully explains this plan of inter-
ttent regulation.

20. As shown by the great uniformity of flow in their connecting
ers when compared with other streams of corresponding magni-
le, the Lakes themselves in their natural state regulate the flow in
se rivers automatically and far more perfectly than can be done
human agency. Artificial regulation is impracticable because of
utter impossibility of predicting precipitation, run-off, and
poration for one or more years in advance of needs. Moreover,

it is in the connecting rivers that the limiting depths available fo navigation have usually been found, and there the depth might b affected unfavorably by any plan involving storage. To preven dangerous interference with this beneficial natural adjustment of th flow, compensation must be attempted only so far as will not interfe with natural oscillations.

21. The diversion at Chicago transfers from the drainage basin the Lakes to that of the Illinois River a considerable portion of th water supply which naturally belongs to the Great Lakes and lowe the level of the entire system from and including the lower sills of th locks in the St. Marys River down to the mouth of the St. Lawrenc The water once diverted at Chicago is forever lost to the St. Lawren Basin. To restore the natural depths of the channel in the lower S Lawrence River is impossible except by dredging, and in the upp St. Lawrence only by more or less extensive and expensive works.

22. The loss of depth on Lake Ontario, due to a diversion of 10,0 second-feet, would be 0.431 foot, or 5.2 inches. The closure of t Gut Channel of the Galops Rapids by the Canadian Government 1903 has had the effect of raising the level of Lake Ontario by abo the same amount. No further compensation is therefore at prese necessary on Lake Ontario to restore its natural levels. The he of Galops Rapids will probably afford an advantageous site for submerged dam or weir to obstruct further the area of the chann through which Lake Ontario discharges, and no great engineeri difficulty should be experienced in securing any reasonable increa of level on this lake, but storage in this lake would, temporarily least, diminish depths in the St. Lawrence River. On plate 7 is sho an extract from the Lake Survey chart of the locality, where ad tional compensation works may most readily be built when desire

23. For the channels and lakes from the foot of Lake Erie to t St. Marys Locks, so far as affected by the Chicago diversion, a pl of compensation seems feasible which will not disturb natural co ditions.

24. To compensate for the reduction of level in Lake Erie, t outflow capacity of the Niagara River must be diminished. building submerged weirs or contraction works a short dista below its head, this may be done without altering the range and t periods of the natural oscillations of the lake. At the same tin the free flow down the Niagara River will remain practically u changed. A proper location of the weirs, which will be of moder height, or of the contracting dikes will not increase the danger ice gorges in the upper Niagara River. A diversion of 10,000 cu feet per second at Chicago would lower Lake Erie 0.45 foot. We and contraction works may safely be built in the portion of t Niagara River at the foot of Squaw Island, near Austin Stre shown on plate 7, and computation shows that to produce a rise 0.45 foot on Lake Erie, the rise at Squaw Island must be 0.85 fo Three weirs, one at the foot of Squaw Island, the others half a m above and below, respectively, and averaging 4.2 feet in height ab the present river bed will produce the desired rise of 0.85 foot Squaw Island and will thereby compensate for the diminished lev of Lake Erie. With a top width of 6 feet and side slopes of 3 ho zontal to 1 vertical, these three weirs would contain about 15, cubic yards of material and, if built of solid masonry, at $10

rd would cost $150,000. In place of these submerged weirs con-
action works at the same locality would produce the same result at
mewhat higher cost, but to avoid undesirably great effects at
gher stages these contraction works should not extend above
ean stage.

25. It is known that when the surface of Lake Erie is elevated
ere will be some backwater effect on Lakes Michigan and Huron,
timated to be slightly more than one-third the rise of Lake Erie.
ssuming the surface of Lake Erie raised 0.45 foot, it is estimated that
e backwater rise of Lakes Michigan and Huron may be as much as
16 foot. A diversion of 10,000 second-feet at Chicago would
wer Lakes Michigan and Huron 0.47 foot, and the difference between
is and the above backwater effect, or 0.31 foot, represents the
ditional amount which the surface of Lakes Michigan and Huron
ust be raised to compensate for such diversion. The St. Clair
ver is a main artery of the highly important lake traffic, and if
bmerged weirs are to be built in this river to raise the level of
kes Michigan and Huron, sites must be chosen and the weirs built
such height that the depth over them will be ample and that
vigation may remain convenient and unobstructed. The average
pth of the St. Clair River for a considerable distance below the
uth of Black River at Port Huron is 30 feet, and six weirs may
built below that point, at distances averaging half a mile apart,
ich will raise the surface of Lakes Michigan and Huron the desired
ount and will not reduce the depth over the weirs and elsewhere
low 24 to 25 feet. The mean velocity of the current in this vicinity
uld be increased from about 3.28 feet to about 3.89 feet per second,
to about 2⅔ miles per hour, and the effect of this increase would
felt over a distance of about 3 miles below the upper weir, while
ove it the river slopes and velocities, now excessive, will be dimin-
ed and navigation will be benefited. The weirs, located as above,
ould have a height of about 5 to 6 feet above the river bed, and
weirs would require about 65,000 cubic yards of stone, which,
$5 per cubic yard, will cost about $325,000. Contraction works
the same locality will, at higher cost, produce the same result,
t they must, as previously noted, be restricted in height to mean
ge.

26. The Chicago diversion, nor any from the lower lakes, will have
effect upon Lake Superior.

27. The plan of compensation herein proposed has the advantage
simplicity and relative economy. Moreover, the submerged weirs
y be systematically and progressively built, so as to permit close
servation of their effect and such changes in plan as experience
ned during construction may suggest. On the other hand, the
agara River weirs, so long as they exist, would certainly interfere
h the navigation of the main channel of the Niagara River and at
ne future time might thereby interfere with the deepening of the
annel. Present navigation would, however, be sufficiently served
the new lock at Black Rock. A further minor criticism of the
posed Niagara River weirs is that they do not, as would a high
ir close to Niagara Falls, prevent the power diversions at Niagara
m slightly lowering the level of Lake Erie; but the weirs are
igned to compensate for the effects of diversions from Lake Michi-
n only. The consideration of compensation for the effects of diver-

sions from the Niagara River is not included in the board's dutie but such compensation could readily be provided by slight modification of the weirs proposed.

28. Compensation for the loss of elevation on Lakes Michiga Huron, and Erie and connecting waters, due to an assumed diversio from Lake Michigan of 10,000 second-feet will, by the plan abov outlined, involve a total expenditure of at least $475,000, to whic must be added a small amount, possibly $15,000 annually, for th maintenance of the remedial works. This volume of 10,000 cub feet per second has been assumed merely as a basis for computatio The cost of compensation for a diversion of different volume may determined in the same manner. The cost of these compensati works is only part of the price that must be paid because of an diversion from Lake Michigan, and it is believed that this at lea should be paid by the direct beneficiary of the diversion.

C. Keller,
Major, Corps of Engineers.

LETTER OF MR. FRANCIS C. SHENEHON.

Minneapolis, *October 12, 1912.*

Board of engineers on Lakes to Gulf Waterway.

Sirs: 1. On behalf of the Hydraulic Power Co. of Niagara Falls, I have placed your hands two blue prints,[1] showing in plan and in section a proposed submerg rock weir in the Niagara River above the Cataract Rapids. This weir will rea from Port Day to the Canadian shore.

2. These blue prints are submitted, and this statement of the object of the we because I understand that the compensation of the water diverted by the Chica Drainage Canal or by the Lakes to Gulf Waterway is a part of the matter to be cluded in your report.

3. It is well known to you that at the present time 15,100 cubic feet per seco of water is diverted from the Niagara River above the crest of the rapids by the t large American companies. It is further known that the treaty with Great Brit permits a diversion ultimately of 20,000 cubic feet. It has been reported that diversions of the above amounts in the Niagara River cause some small lowering of river in this vicinity. The object of this weir is to raise the water level in the Gr Island-Chippewa Pool to the betterment of navigation, and in compensation of computed lowerings from diversions in the Niagara River itself and at Chicago.

4. The weir is built of bastard limestone in large blocks and will have a cr width of about 100 feet. As designed it will require about 42,000 yards of rock a its crest level will be about 6 feet below mean water level.

5. The rise in the river due to this compensating weir will be approximately follows:

Lake Erie level.	Volume of flow in square feet.			Rise caused by weir.
	River.	Diversion.	Over weir.	
Feet.				*Feet.*
571.26	180,500	19,500	161,000	0.62
572.26	202,500	19,500	183,000	.58
573.26	224,500	19,500	205,000	.55
574.26	246,500	19,500	227,000	.52

The greater rise for low water is beneficial to navigation.

6. As to the method of computing the effect, it should be stated that engineer literature does not contain any great help in a problem of this kind, except a teaches certain fundamental hydraulic principles which govern flowing water. T river section on the line of the proposed weir has an area of 38,400 square feet, wh

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[1] Not printed.

ass Island-Chippewa Pool is at elevation 562.32, and the discharge of Lake Erie
r its corresponding elevation is 224,500 cubic feet per second. Of this 19,500 cubic
et is taken as diverted above the weir. This leaves the flow over the weir 205,000
bic feet per second, with a mean velocity of 5.34 feet per second. When the sec-
n of the river is reduced to 27,200 square feet of area by the rock weir, the mean
locity must be 7.54 to pass the flow. In order to speed the water up to this velocity,
head of 0.43 foot with 100 per cent efficiency is required. As some wasted effort
ters, the efficiency of the velocity head is taken at 80 per cent, and the river rise
ust then be 0.54 foot, or, in view of some uncertainties, 6 inches roundly.

7. This operation may be expressed by the following equation:

$$R=\frac{\left(\frac{Q'}{a}\right)^2-\left(\frac{Q'}{A}\right)^2}{2gk}$$

In this equation—
R is the river rise created, in feet.
Q′ is the discharge over the weir, in cubic feet per second.
A is the natural cross-sectional area of the river, in square feet.
is the river section, with the weir constructed, in square feet.
is the acceleration of gravitation, 32.2.
is a coefficient of flow, taken here as 0.80.

. It should be stated that it is not necessary to build any more of this compensat-
weir than will give the desired change or rise in the water level. As the con-
iction progresses water gauges at Buffalo, at Chippewa, at Suspension Bridge, and
the Whirlpool will measure accurately the effect produced. When enough rise
ecured, the construction may be stopped. Should the weir as designed be insuf-
ent, some small addition will bring the rise to the proper amount. For this reason
proposition does not rest on any involved mathematical deductions.

. It should be stated that the rise in river elevations due to this submerged rock
r will have its maximum value of about 6 inches just above its crest, and that the
in Lake Erie will be about 1 inch. Between these two points the rise in river
el will vary somewhat as the distance upstream above the weir.

). This submerged rock weir is suggested to the Board of Engineers as an engineer-
proposition which will be beneficial to the navigation of the river and as tending
ompensate more than twice the effect which could possibly be attributable to
diversions present or anticipated of this particular company. It is known to
board that the authorized diversion of this company is 6,500 cubic feet per sec-
, and that the actual diversion is slightly less than this. The original recommen-
on of the American section of the International Waterways Commission for the
ntity of water to be apportioned to this company was 9,500 cubic feet per second,
was based on the commission's interpretation of the charter rights of this com-
y from the State of New York. Their canal has a capacity for this flow. Should
Government issue a permit to the Hydraulic Power Co. to divert this additional
0 cubic feet per second, it might attach as a condition thereto that the company
ıld contribute toward the expense of the proposed submerged weir. It is under-
d that the jurisdiction of this board does not touch the question of additional
rsions to be authorized. It does seem proper, however, to state the condition
er which the company might be called upon to contribute to a construction which
compensate for the lower river, not alone their desired diversion, 9,500, but will
pensate in addition, in the immediate vicinity of Port Day, a diversion of 10,000
ic feet per second at Chicago.

espectfully submitted.

Francis C. Shenehon.

LETTER OF MR. FRANCIS C. SHENEHON.

Minneapolis, *October 29, 1912.*

he Board of Engineers on Lakes-to-Gulf Waterway.

rs: 1. In addressing you upon the subject of the regulation of Lake Erie, I wish
xpress my feeling of personal humiliation that, after so many years of investiga-
of all the hydraulic elements involved in making Lake Erie, the Detroit River,
Lake St. Clair better navigable ways, nothing has been accomplished up to
present time in regulation. The low water on the Great Lakes of 1895–96 demon-
ed the fatuity of letting unrestricted natural conditions produce random results.
was economically most harmful to the carrying trade of the Great Lakes.

2. As a result of the low water of 1895-96, the Angell-Cooley-Russell Commissio recommended the appointment of a board of engineers to investigate the subject regulation, in connection with the larger subject of waterways to the sea.

3. In the report of the resulting board, consisting of Col. Raymond, Alfred Noble and George Y. Wisner, the regulation of Lake Erie was specifically recommended The distinguished personnel of this board gives great weight to its recommendatio In some respects, however, the scheme of the board was criticized. An attempt wa made in the scheme of regulation to maintain Lake Erie at a level probably too hig for all the conditions involved. The regulating works were to be placed above th head of the river, and with piers spaced so close together that the retardation of th ice fields was likely to be brought about. In addition the expense of building th regulating works was very considerable. The report of this board was made in 189

4. The present International Waterways Commission, so far as may be learned fro its report of 1910, is not likely to make any recommendations for the regulation Lake Erie, but will report in favor of compensating works instead. It is understo that the functions of this commission so far as international boundary streams a concerned has now been taken over by the commission created by the treaty of 19 with Great Britain. Unless your honorable board should find the regulation of La Erie a proper subject for report, this important matter is likely to be relegated to commission not of engineers.

5. My own investigations and studies of the hydraulics of the Niagara River, beg in 1898, have convinced me that a considerable betterment of the level of Lake Eri of the Detroit River, and Lake St. Clair is entirely feasible at a reasonable expen ture for controlling works and at a small cost for maintenance. It was estimated the Angell-Cooley-Wisner Commission that a foot in depth on Lake Erie harbo would save in dredging operations $1,000,000. This estimate, I understand, does n take into consideration the shallow west end of Lake Erie, including the approach the Detroit River, the Detroit River itself, and Lake St. Clair.

6. The question of the regulation of Lake Erie has grown additionally importa by reason of the entrance of two elements other than navigation. These are t desirability of maintaining scenically effective the cataract at Niagara Falls, wh the average flow over the cataract is diminished by such considerable quantities water as are authorized by the treaty with Great Britain, and the need of maki the diverted water, under the treaty with Great Britain, as efficient as possible a power resource of the people of two nations. While navigation may still be regard as predominant, the economic value of water power in the Niagara River and t æsthetic value of a spectacle internationally in trust must receive the high consideration.

7. In presenting to you a scheme for the regulation of Lake Erie it is believed t the method used will be helpful to the three things involved—navigation, wa power, and scenic grandeur.

8. It may be claimed for the method of regulation used that while it does not a to hold Lake Erie within narrow limits, it will better the low-water level of the l by at least a foot, and that no danger will arise from the method used of excess high water.

9. It is a well-known fact that ice in the St. Lawrence River so retards the river f that Lake Ontario is on an average about 7 inches higher than it would be in absence of the winter season. It is well known also that the flow of the St. C River is at times much reduced by ice conditions. It has been estimated that value of the ice period on the levels of Lakes Michigan and Huron is perhaps 6 inc The peculiar beauty of the ice regulation is that during the season of navigation a vestige of the ice-regulating works remains. They have completely disappea and have left the channels in their full outflow sections. The peculiar disadvant of the ice dam lies in the fact that this formation bears no relation whatever to n but is a function of the coldness of winter. The coldest winter may come at a t when the lake has no need of any further lift. In the Niagara River the effect of is practically negligible so far as the level of Lake Erie is concerned.

10. The regulating works recommended by me take the one from nature and ice dam by providing a form of dam which practically retains, when the gates lifted, the original outflow section of a river. This insures the avoidance of und high lake stages.

11. It is proposed to place three piers on the solid limestone bottom of the u Niagara River, perhaps a thousand feet below the Buffalo Water Works' intake These three piers, with gates to work from truss work built upon these piers, interc when the gates are lowered, about 500 feet of the river flow. The piers are space as to have a clear waterway of 240 feet. With this clear waterway between pier danger of ice blockades will be present. This is a known fact because the I

ational Bridge crossing the river a little further below has clear openings of from
87 feet to 235.8 feet. The clear openings for the regulating works proposed by me
re greater than any opening of the International Bridge. The plan proposed is
hown in sheet 1 appended to this report.

12. The regulating works are designed to lessen the river flow at any time by about
0,000 cubic feet per second. Should the gates remain permanently closed, this
ould result in raising Lake Erie a little less than a foot and a half. It is purposed,
owever, to operate the gates so that the flow is intermittent. That is, the gates
uring the open season will perhaps be wide open during certain of the daylight
ours and closed during the night hours. The effect of this will be to create night
nservation for larger daylight flow. The resulting effect on Lake Erie will, as before
ated, be perhaps a betterment in level of 1 foot. It should be stated, however, that
he betterment of level would consist in the avoidance of levels below 573 rather than
n any attempt to keep the lake at high lake levels.

13. The conditions leading to the intermittent regulation of the flow of the Niagara
iver are developed from the following conditions of the three uses of the water of
ake Erie and the Niagara River. Only one use, that for power, needs to go on con-
nuously 24 hours a day, and every day in the year. Navigation has a duration of
months out of 12. Scenic grandeur, so far as it depends on great volume of flow, may
e limited to the six months, May to October, inclusive, and to the daylight hours of
ose months. As pointed out in my report on the preservation of Niagara Falls
. Doc. No. 105, 62d Cong., 1st sess.) during the winter months volume of flow is
bordinated, because ice and frost effects add new scenic beauty, and because visi-
rs are few; perhaps a tenth of all visitors coming in the months November to April.

14. Notwithstanding the closing in of the night or the absence of seeing eyes, the
lendid barbaric prodigality of nature maintains the seaward rush of the waters.
st a little lessening comes in the midwinter months, when ice affects a slight restraint.
uring the night hours a chance is presented to lessen the prodigal waste and to store
water to maintain in the daylight spectacle much of its natural grandeur.

15. Taking 200,000 cubic second-feet as the mean river flow, after deducting all
-lake diversions, and 572.2 as the corresponding Lake Erie elevation, suppose by
oper controlling works at the head of the Niagara River the flow is increased to
0,000 cubic second-feet during 8 hours each day and reduced to 190,000 feet for
hours. Exactly the same amount of water is discharged from Lake Erie in the
hours, and no effect whatever appears on Lake Ontario. To accomplish this large
crease of daylight discharge Lake Erie must be as high as elevation 573.1, and the
ntrolling works must be designed to shut off 30,000 cubic second-feet, or 15 per cent
the mean flow. Tentative figures indicate that a section of controlling gates from
0 to 500 feet in length will suffice to accomplish the change in flow desired.

16. The evolution of this simple method of nighttime storage is interesting.

On page 76 of my report on the Preservation of Niagara Falls is the following:

‘The Falls are operative only as a scenic spectacle during the daylight hours.
hen the night shuts in partial depletion would not be scenically injurious. Such
rmits issue for half the flow of the river from sunset to sunrise, or for 12 or 16 hours
ery day, a tremendous power would become available that would furnish its own
ht, and factories might work by night instead of by day. The temporary lowering
the river would immediately readjust itself when the sunrise shutdown came. The
erference with night navigation on the river would not be prohibitive in view of
e benefits to be conferred in cheap power and light. The use of the night power at
agara implies regulation of Lake Erie's outflow.''

Maj. Charles Keller, of the Corps of Engineers, in commenting on my suggestion,
s tes (p. 16, S. Doc. 105):

‘As compensation for the restrictions necessarily imposed, the suggestion * * *
t t the power companies be permitted to use half the flow of the river between sunset
a l sunrise is worthy of consideration. Many factories now run at night, and if the
r e for power used between sunset and sunrise were made appreciably lower than
t rate ruling during daylight hours, the amount of night use would probably increase.
urther development of the storage battery might even render it commercially pos-
s le to use in the daytime the surplus power of the larger volume of night diversion.
S h enlarged use of water at night, unless compensated, would result in a lowering
o he level of Lake Erie. The necessary compensation works should, of course, be
e cted at the expense of the beneficiaries—the power companies.''

he storage battery mentioned has its counterpart in the proposed storage of water
i Lake Erie, for the purpose of making practicable the utilization of water accord-
i to the treaty with Great Britain, without diminishing too greatly the volume of
fl on which the scenic grandeur largely depends. Instead of electric potential in
tl battery, the storage of water gives hydraulic potential.

17. As to the regulation of Lake Erie, it is not purposed necessarily to lessen th amplitude of the yearly stage cycle, except in the avoidance of elevations below, say 572.5 and above 574. The flow should be unrestricted during the months of January February, March, and April to avoid low river levels. The gates may be continuousl closed during November and December. During the months May to October, inclu sive, storage by night with a river flow of 190,000 cubic second-feet and by day heavy flow of 220,000 feet would be the normal condition.

18. No detailed analysis of the effect to be produced on Lake Ontario has been mad It should be understood, however, that the initial impounding to bring Erie to a annual mean elevation of 573.1 should be at a time of generous supply. The holdu of 10,000 cubic second-feet in November and December will raise Erie 0.3 feet an lower Ontario 0.4 feet. The increased flow of January to April will compensa these changes. In periods of scant supply, as in 1895–96, an adjustment betwee Erie and Ontario would need to be made.

19. As regards Michigan-Huron, a betterment of Erie's level by 10 inches may li these lakes 3 inches. Lake St. Clair would benefit to the extent of 6 inches or mor

20. The results to be obtained will be a betterment of conditions for the pow companies, because the greater winter flow will lessen the difficulties coming fro combinations of ice and low water. Nighttime storage will return to the daylig flow an amount of water equal to that permissible for the American side at Niaga Falls under the treaty with Great Britain. Navigation in Lake Ontario will n suffer substantially, and navigation in Lake Erie and above will be greatly improve

Francis C. Shenehon.

Appendix B.

THE INFLUENCE ON VOLUME AND HEIGHT OF WATERS IN THE MISSI SIPPI RIVER BELOW CAIRO.

New York, *August 13, 1913.*

Brig. Gen. William H. Bixby,
President, Lakes to Gulf Waterway Board.

Sir: I have the honor to submit the following report upon the i fluence on volume and height of waters in the Mississippi River bel Cairo by reason of any diversion of water from Lake Michigan for t maintenance of the proposed Lakes to the Gulf Waterway.

The influence in volume of any diversion from Lake Michigan w be an increase in discharge approximately equal to the amount the diversion, since the losses due to evaporation and other causes w not be large. At ordinary low water the percentage of increase in t volume of discharge due to the present authorized diversion will va from about 2½ per cent at Cairo to 1½ per cent at New Orleans, a at extreme high water will be less than one-fourth of 1 per cent fr Cairo to the mouth of the river.

Except as increase in volume results in increases of gauge heig or of depth of water available for purposes of navigation, it will be no importance within any limits of diversion heretofore considered permissible.

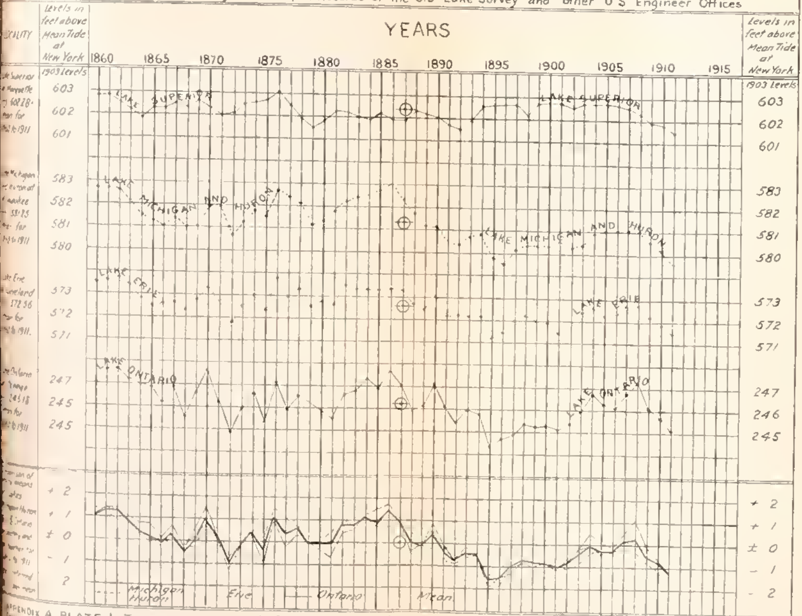
The effect of any diversion upon gauge height will always be sm and at the highest stages practically nothing, but the exact effect any time or at any stage is impossible to determine, since this eff will be complicated or obscured by various other changes in regimen of the river.

An extended series of discharge observations of the Mississi River was taken under the direction of the Mississippi River Co

SURFACE LEVELS OF THE GREAT LAKES

CURVES OF ANNUAL MEANS OF EACH LAKE FROM 1860 TO 1911.

Under direction of Brigadier General W H BIXBY, Chief of Engineers, Washington, D C, November 1911
Drawn in Office of U S Lake Survey Based upon Records of the U.S Lake Survey and other U S Engineer Offices

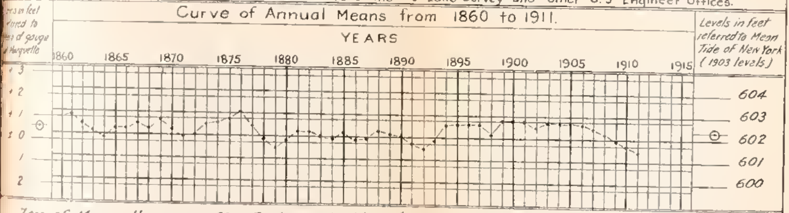


APPENDIX A PLATE I To accompany report of Board appointed by Secretary of War in S O * 43 Office of Chief of Engineers U S Army Sept 8.1910

WAR DEPARTMENT. CORPS OF ENGINEERS, U.S. ARMY.

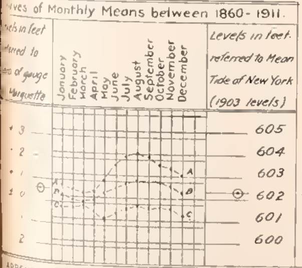
SURFACE LEVELS OF LAKE SUPERIOR AT MARQUETTE, MICH.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers Washington, D.C., November, 1911.
Drawn in Office of U.S. Lake Survey Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Curve of Annual Means from 1860 to 1911.

Zero of Marquette gauge = 601.75 above New York (U.S. Lake Survey level adjustment of 1903)
Mean level for 1876 or highest annual mean = 603.06, Highest monthly mean = 604.08. Sep. 1869.
" " 1879 lowest " " = 601 43 Lowest " = 600 54 Apr 1911
" " Averages for 52 years or for 1860 to 1911 incl. = 602.28 (see in side columns)



Curves of Monthly Means between 1860-1911.

A - curve of 1876 or year of highest annual mean.
B - " " averages for 52 years 1860 to 1911.
C - " " 1879 or year of lowest annual mean
⊙ Represents the Average for 52 years, 1860 to 1911 incl. = 602 28

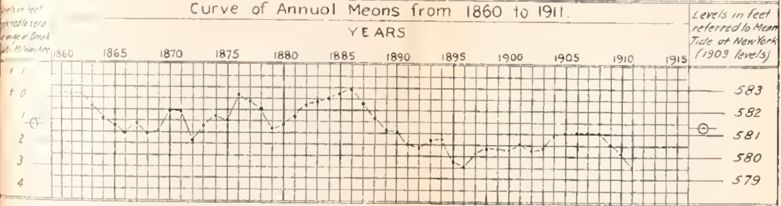
APPENDIX A PLATE 2. To accompany report of Board appointed by Secretary of War in S.O. # 43 Office of Chief of Engineers U.S. Army Sept 8 1910.

House Doc. No. 762; 63d Cong., 2d Sess.

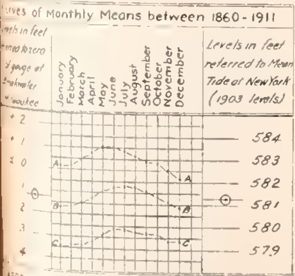
WAR DEPARTMENT. CORPS OF ENGINEERS, U S ARMY.

SURFACE LEVELS OF LAKE MICHIGAN AT MILWAUKEE, WIS.

der direction of Brigadier General W. H. BIXBY, Chief of Engineers, Washington, D.C., November, 1911.
own in Office of U.S. Lake Survey. Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices



Zero of Milwaukee gauge = 582.53 above New York (U.S. Lake Survey level adjustment of 1903)
Mean level for 1886 or highest annual mean = 582.96 Highest monthly mean = 583.57 June, 1886
" " " 1896 " lowest " = 579.47 Lowest " " = 578.98 Dec. 1895
" " Averages for 52 years or for 1860 to 1911, incl. = 581.25 (see ⊙ in side columns)

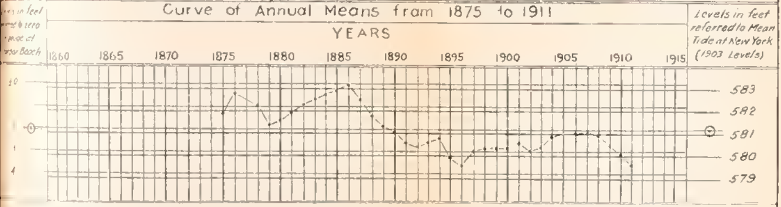


A = curve of 1886 or year of highest annual mean
B = " averages for 52 years 1860 to 1911.
C = " " 1896 or year of lowest annual mean
⊙ Represents the Average for 52 years, 1860 to 1911, incl. = 581.25

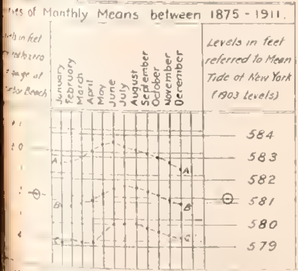
PPENDIX A PLATE 3. To accompany report of Board appointed by Secretary of War in S.O. #43 Office of Chief of ngineers, U.S. Army Sept 8 1910

SURFACE LEVELS OF LAKE HURON AT HARBOR BEACH, MICH.

nder direction of Brigadier General W H BIXBY, Chief of Engineers, Washington, D.C., November, 1911
rawn in Office of U.S. Lake Survey, Based upon Records of the U S Lake Survey and other U S Engineer Offices


Curve of Annual Means from 1875 to 1911

Zero of Harbor Beach gauge = 583.21 above New York (U S Lake Survey level adjustment of 1903)
Mean level for 1886 or highest annual mean = 583.08 Highest monthly mean = 583.66 July 1876.
" " " 1896 or lowest " " = 579.53 Lowest " " = 579.02 Dec 1895
" " " Averages for 37 years or for 1875 to 1911 incl = 581.14 (See ⊖ in side columns.)


ves of Monthly Means between 1875 - 1911.

A - Curve of 1886 or year of highest annual mean
B - " Averages for 37 years, 1875 to 1911
C - " " 1896 or year of lowest annual mean
⊖ Represents the average for 37 years 1875 to 1911 incl = 581.14

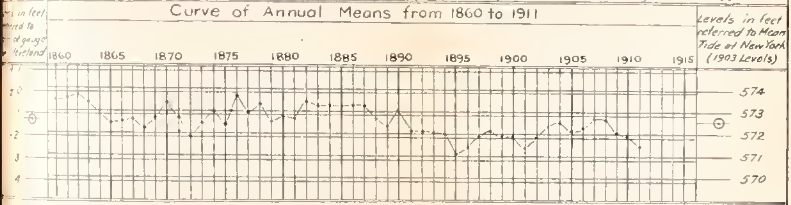
APPENDIX A PLATE 4. To accompany report of Board appointed by Secretary of War in S O * 43 Office of Chief of Engineers U.S. Army Sept 8.1910.

House Doc. No. 762 **; 63d Cong., 2d Sess.**

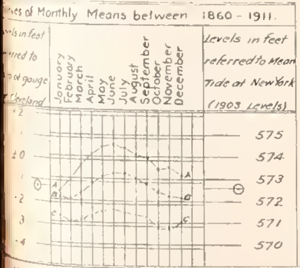
AR DEPARTMENT CORPS OF ENGINEERS, U S ARMY.

SURFACE LEVELS OF LAKE ERIE, AT CLEVELAND, OHIO.

direction of Brigadier General W H BIXBY, Chief of Engineers Washington, D C., November, 1911.
awn in Office of U S Lake Survey. Based upon Records of the U.S Lake Survey and other U S Engineer Offices



Zero of Cleveland Gauge 573.82 above New York (U S Lake Survey Levels of 1903)
Mean Level for 1876 or Highest Annual Mean = 573.70. Highest Monthly Mean = 574.52 June 1876
" " " 1895 " Lowest " " = 571.17. Lowest " " = 570.70 Nov. 1895
" " Averages for 52 Years or for 1860 to 1911 incl = 572.56 (see ⊙ in Side Columns)



A. Curve of 1876 or of highest annual mean
B. " " Averages for 52 years 1860 - 1911.
C " " 1895 or of lowest annual mean
⊙ Represents the Average for 52 years 1860 to 1911 incl. = 572.56

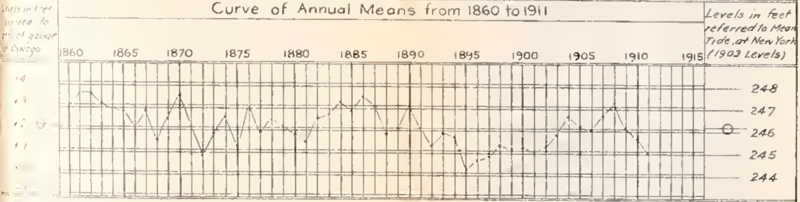
APPENDIX A PLATE 5. To accompany report of Board appointed by Secretary of War in S.O.# 43. office of Chief of Engineers U.S Army Sept 8 1910

House Doc. No. 762 ; 63d Cong., 2d Sess.

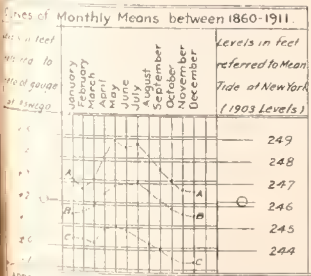
WAR DEPARTMENT. CORPS OF ENGINEERS U.S ARMY

SURFACE LEVELS OF LAKE ONTARIO AT OSWEGO, N. Y.

der direction of Brigadier General W H BIXBY, Chief of Engineers, Washington, D C., November 1911
wn in Office of U S Lake Survey, Based upon Records of the U S, Lake Survey and other U.S Engineer Offices



of Oswego Gouge 244 12 above New York (U.S. Lake Survey level Adjustment of 1903)
Mean Level for 1862 or Highest Annual Mean = 247 63 Highest Monthly Mean = 248.95, May 1870
" " 1895 " Lowest " " = 244 29 Lowest " " = 243. 41, Nov 1895
" " Averages for 52 years or for 1860 to 1911 incl. = 246. 18 (see -⊖- in Side Columns.)

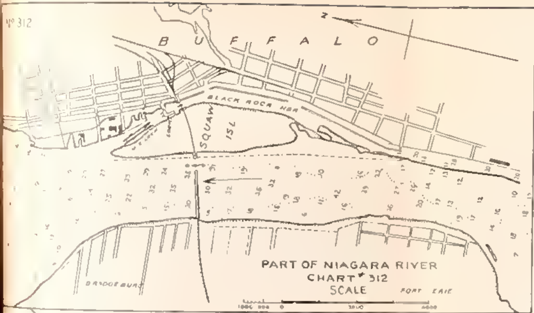


A = Curve of 1862 or year of highest annual mean
B = " " Averages for 52 years, 1860 to 1911
C = " " 1895, or year of lowest annual mean
-⊖- Represents the Average for 52 years 1860 to 1911 incl = 246.18

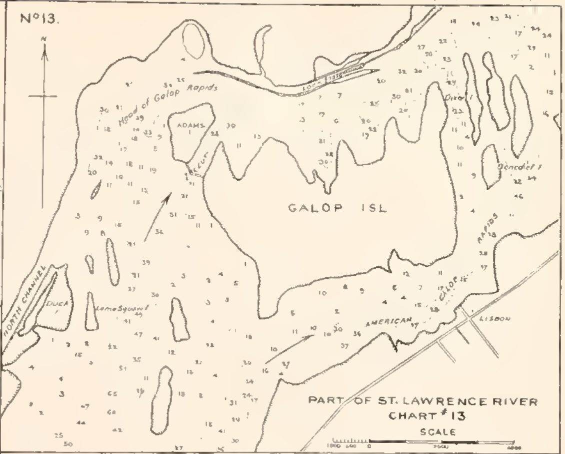
APPENDIX A, PLATE 6 To accompany report of Board appointed by Secretary of War in S.O. # 43 Office of Chief of Engineers U.S Army Sept 8 1910

WAR DEPARTMENT.

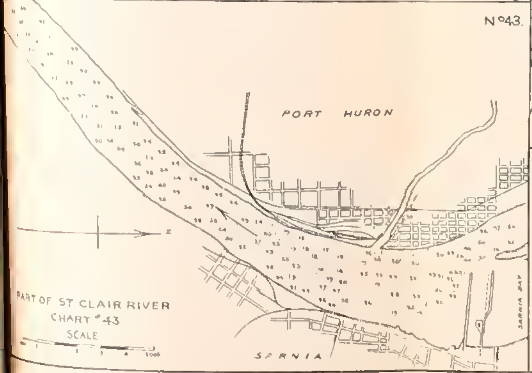
CORPS OF ENGINEERS, U.S ARMY.


No 312

PART OF NIAGARA RIVER
CHART # 312
SCALE


No 13.

PART OF ST. LAWRENCE RIVER
CHART # 13
SCALE


No 43.

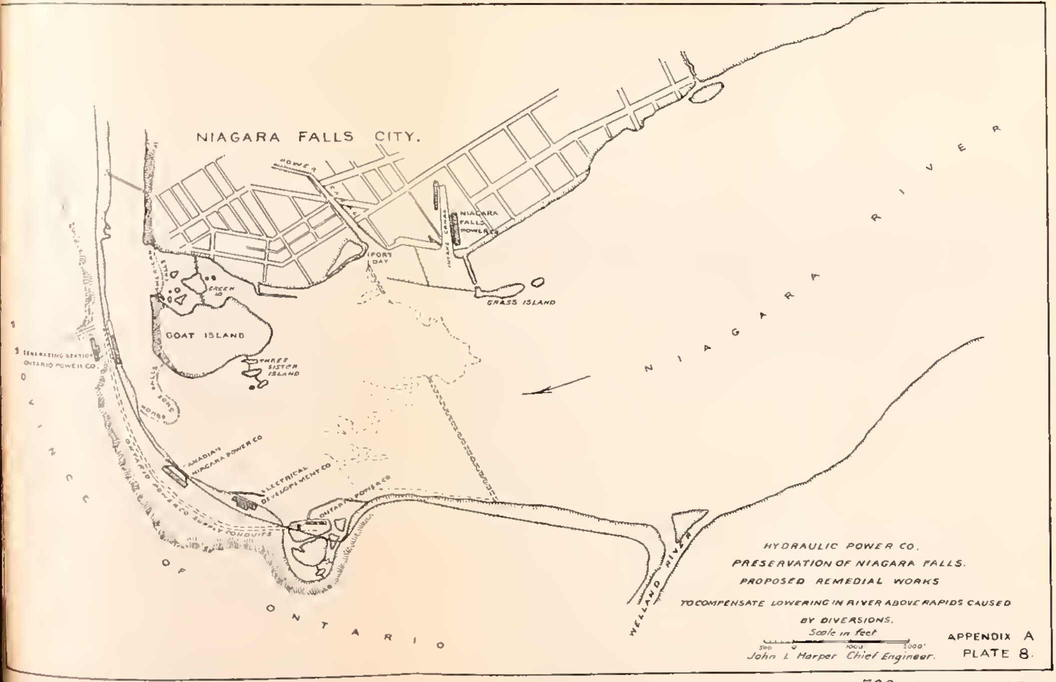
PART OF ST CLAIR RIVER
CHART # 43
SCALE

Extracts from U S Lake Survey Charts Nos 13, 312, and 43 showing approximate locations of suggested compensation works

To accompany Appendix A of Report of Board appointed by Secretary of War in S.O. 43 Office of Chief of Engineers U S Army Sept 8 1910.

APPENDIX A

PLATE 7.



HYDRAULIC POWER CO.

PRESERVATION OF NIAGARA FALLS.

PROPOSED REMEDIAL WORKS

TO COMPENSATE LOWERING IN RIVER ABOVE RAPIDS CAUSED BY DIVERSIONS.

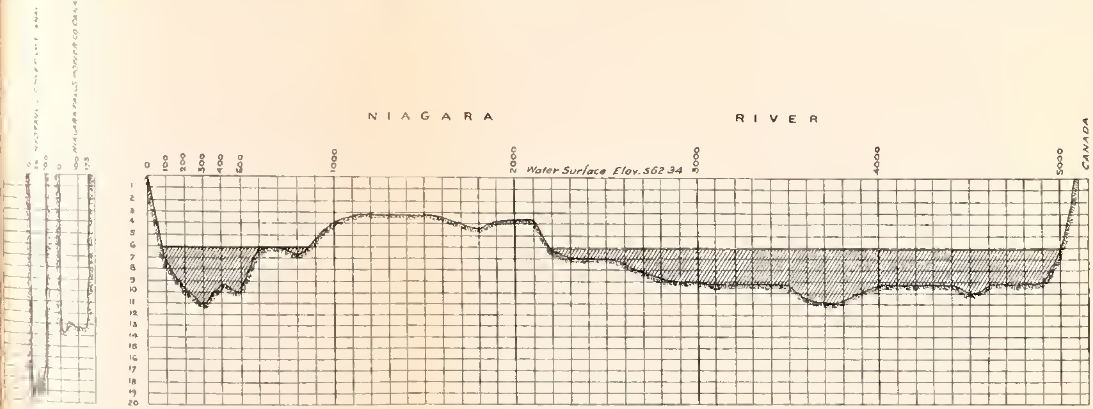
Scale in feet

John L Harper Chief Engineer.

APPENDIX A
PLATE 8.

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY.



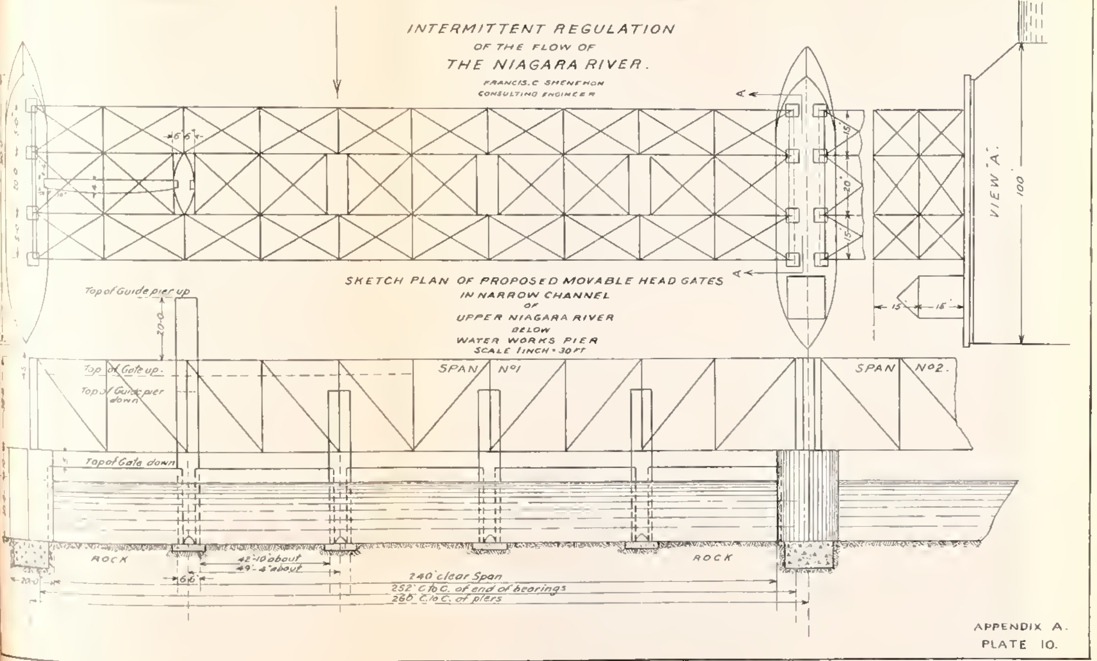
Note Water surface Elevation 562.34 is equivalent to Lake Erie Elevation 573 26

HYDRAULIC POWER CO
CROSS-SECTION OF RIVER
BELOW PORT DAY AND CHIPPEWA
SHOWING PROPOSED COMPENSATING WEIRS.
ALSO
CROSS-SECTION OF POWER CANAL
ON AMERICAN SIDE
HOR SCALE 1" = 500'
VERT " 1" = 8'
JOHN L HARPER CHIEF ENGINEER

APPENDIX. A
PLATE 9.

INTERMITTENT REGULATION OF THE FLOW OF THE NIAGARA RIVER.

FRANCIS C. SHENEHON
CONSULTING ENGINEER



SKETCH PLAN OF PROPOSED MOVABLE HEAD GATES
IN NARROW CHANNEL
OF
UPPER NIAGARA RIVER
BELOW
WATER WORKS PIER
SCALE 1 INCH = 30 FT

APPENDIX A.
PLATE 10.

ission from 1879 to 1885, at Columbus, Ky., below the mouth of the
hio River; at Helena, Ark., below the mouth of the St. Francis
iver; at Arkansas City, Ark., Wilsons Point, Miss., and Hays Land-
g, below the mouths of the White and Arkansas Rivers; at War-
nton, Miss., below the mouth of the Yazoo River; at Red River
anding and at Carrollton, La. Mean discharge curves have been
rived from these observations, and extended and checked by
merous observations made at later dates.

There is inclosed herewith a drawing containing a set of standard
rves showing the mean or average relation between discharges and
uge heights at Columbus, Ky., Helena, Ark., Vicksburg (and
arrenton), Miss., and Red River Landing, the curves of relation
r a rising river being flatter and for a falling river steeper than
ese standard curves. On the same drawing and at the left of the
rresponding standard curves is also given a second set of curves
owing in tenths of a foot the theoretical increase in gauge heights
any stage due to an increase in discharge of 10,000 cubic feet per
cond, the second set being deduced from the first set by assuming
at the increase in gauge heights due to this increase in discharge
ll be at the rate indicated by these standard curves. From these
o sets of curves some idea can be had as to the increase in gauge
ight at any stage of the river which would result from any diver-
n from Lake Michigan. However, the idea can be approximate
ly, for the increase in gauge heights due to a permanent increase
discharge would be more nearly indicated by the curve of relation
a rising river; and as this is flatter than the standard curve,the
ual increase would probably be less than indicated by the curves
own. Moreover, if the flow of the river at Cairo be permanently
reased by diversion, any resulting increase in gauge height would
ng about increased velocity due to the increase in slope, and the
djustment of conditions which would follow would tend to make
final increase in gauge height due to the diversion less than that
luced from the standard curve shown. Assuming that increase
gauge height will not be accompanied by changes in cross section
river or that its effect will not be otherwise obscured, the diagram
icates that at all four places considered it would require an
rease in discharge considerably exceeding 10,000 cubic feet per
ond to increase the gauge heights by 1 foot even at the lowest
ges of the river. Under similar assumptions, at stages corre-
nding to 40 feet at Columbus, the curves indicate that it would
uire an increase of over 50,000 cubic feet per second to increase
gauge height 1 foot at Columbus, Helena, and Red River Landing,
over 5,000 cubic feet per second to affect the gauge one-tenth of a
t. At higher stages the effect would be even less, and it is evident
t on extreme flood heights the effect of any permissible diversion
ld be trifling and would have no important bearing upon the
ghts of levees or other works designed to afford protection against
ds.

he increase of navigable depths at lower stages due to any diver-
would be less than indicated by the theoretical increase in gauge
ght, for elevation of the surface of the river has been found to be
ompanied by a corresponding, though smaller, elevation of its
.

In the Report of the Board of Engineers on Survey of Mississipp River from St. Louis, Mo., to its mouth, published in House Documen No. 50, Sixty-first Congress, first session, page 44, it is stated as follows

> Repeated measurements (see graphical plot hereto appended) on the bar crossin of the Mississippi between St. Louis and Cairo show that up to a stage of about 20 fe above low water the available depth across the new bar is increased on an averag only about one-half foot for every foot in the rise of water. (Between Cairo and Re River similar measurements show even less increase in navigable depth per foot rise of water surface.)

Due to the permanent character of the diversion, the above rati of elevations of water surface and river bed would not hold, and an permanent increase in gauge height would be less than that indicate by the standard curve, and would represent a change in the regime of the river which would be accompanied by a rise of the river be practically equal to such increase. In any case, the gain in navigab depth would be insignificant for any permissible diversion.

Very respectfully,

J. B. CAVANAUGH,
Major, Corps of Engineers.

APPENDIX C.

(Part 1.)

ST. LOUIS, MO., *August 13, 1913.*

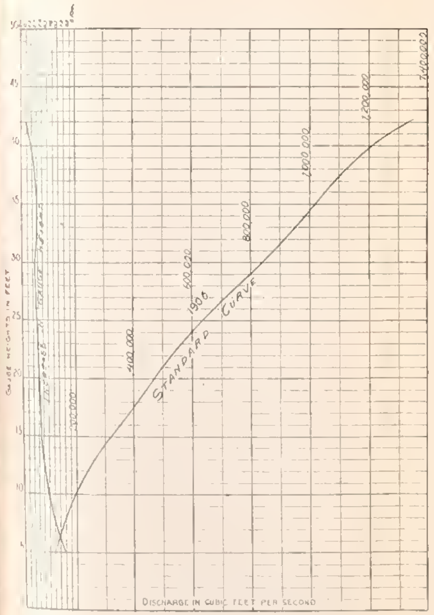
From: Col. C. McD. Townsend, Corps of Engineers.
To: Brig. Gen. W. H. Bixby, U. S. Army, retired, President, Lak to Gulf Waterway Board.
Subject: Effect upon the climate of the Lake States by a change the natural currents of Lake Michigan.

The following report is submitted upon certain observations ma under the direction of the board, to determine the effect upon t climate of the Lake States by a change in the natural currents Lake Michigan.

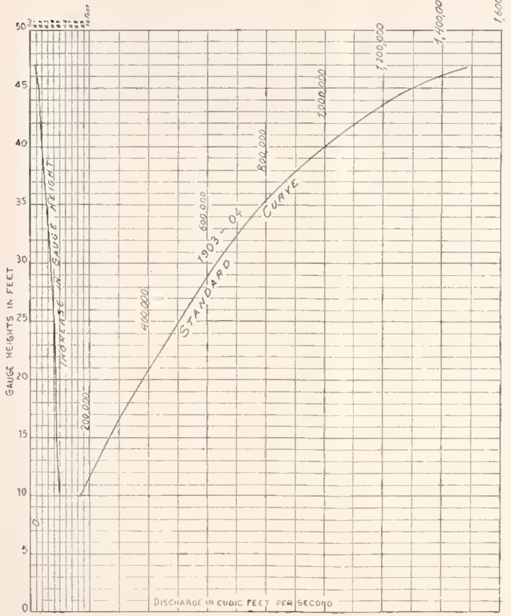
While variations in the levels of the Great Lakes have been carefu studied for a long period on account of their influence on the dep of harbors and connecting waters, it is only during recent years th data have been collected relating to their temperature and curren The information thus obtained is not only incomplete, but the co clusions derived therefrom by different observers are frequen contradictory. The board therefore considered it necessary make a series of independent investigations.

In compliance with instructions from the board, the temperatu of Lake Michigan off Frankfort was determined at different dep to 600 feet. Similar sets of observations were taken in Lake Hu off Harbor Beach, in Lake Erie off Long Point, in the Straits Mackinac, and in the Detroit River. Through the courtesy of Light House Bureau, the temperature of the surface water and and the direction of the currents in Lake Michigan were obser daily during the summer months of 1911 at the lighthouses at C cago, Milwaukee, Grand Haven, White Shoal, and in Lake Hu at Spectacle Reef, Harbor Beach, and the lightships on Poe R and off Fort Gratiot. Daily observations were made of the surf

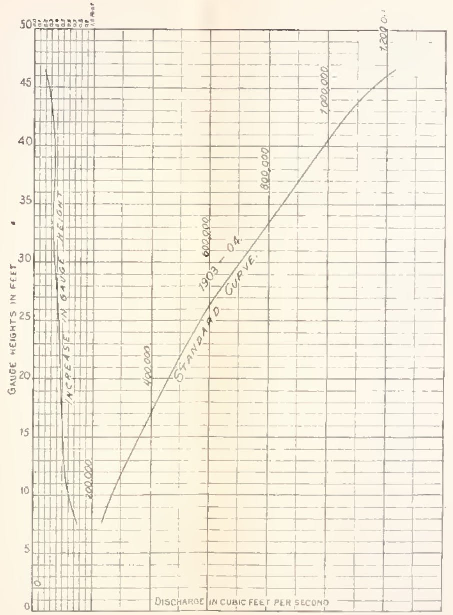
Appendix B
Plate I.



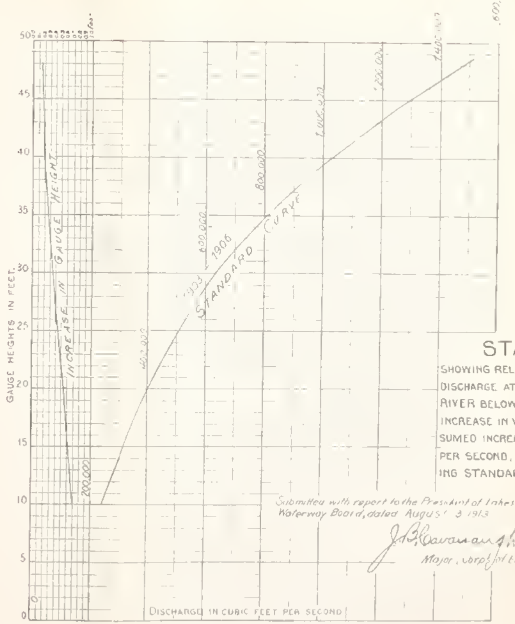
Columbus, Ky.



Helena, Ark.



Vicksburg (and Warrenton), Miss



Red River Landing, La.

STANDARD CURVES

SHOWING RELATION BETWEEN GAUGE HEIGHT AND DISCHARGE AT SELECTED POINTS ON MISSISSIPPI RIVER BELOW CAIRO, ALSO CURVES SHOWING THE INCREASE IN VARIOUS GAUGE HEIGHTS DUE TO AN ASSUMED INCREASE IN DISCHARGE OF 10,000 CUBIC FT PER SECOND, AS DETERMINED FROM THE CORRESPONDING STANDARD CURVES

Submitted with report to the President of Lakes to Gulf Waterway Board, dated August 3 1913

J.B. Cavanaugh
Major, Corps of Engineers
U.S. Army

emperatures of the Chicago and St. Marys Rivers and the Straits
f Mackinac while work was in progress on the breakwater at
ackinac Island. The results obtained at these various stations
re appended. A continuous series of lake levels at Chicago, Mil-
aukee, Mackinac, Harbor Beach, and Fort Gratiot covering the
ame period have been obtained from the office of the Lake Survey,
nd observations of levels at Grand Haven taken three times a day
uring the months of June, July, and August, have been furnished
y the United States Engineer Office at Grand Rapids. The results
these observations are shown graphically on plates 1, 2, 3, and 4.
uring July and August the steamer Hancock circumnavigated Lakes
rie, Huron, and Michigan, and took observations of surface tem-
ratures at intervals of one hour. From the log of the vessel its
urse has been plotted on plate 5 with the temperatures observed.
he results of the observations for Lake Michigan are summarized
the appended tables.

In addition to the observations taken by the direction of the
ard there are available for the investigation a series of observa-
ns of surface temperatures made by the office of the Lake Survey
ring the years 1904, 1905, 1906, 1907, and 1908. A summary of
e monthly means derived therefrom is appended.

The temperatures at different bottom depths in Lake Superior
ve also been recorded and indicate that below 100 feet the tem-
rature of Lake Superior was uniformly 39° F. during the years
served. On a number of vessels the temperature of the feed
ter has been taken during their regular trips around the Lakes, but
se observations were made during different months and at differ-
depths, dependent on whether the vessel was light or loaded, and
somewhat difficult to analyze.

The Weather Bureau in 1892–93 and 1894 made a series of observa-
ns on surface currents of the Lakes by dropping from vessels at
tain localities sealed bottles and noting the places at which they
re recovered. These two known points were connected by curved
es assumed as the paths of the floats. By repeating the observa-
ns a sufficient number of times, it was expected that errors would
eliminated and the law governing the flow of the water discovered.
these means a surface current in Lake Michigan during the
mmer months was deduced as shown in plate 6.

uring the fall of 1909 and 1910 Mr. Fred J. Meno, United States
pector of hulls at Detroit, Mich., made a similar set of observations
h floats thrown from vessels. He also kept a record of the intensity
l direction of the wind while the floats were in the water. The
ults of his observations are shown on plate 5. His deductions are
t the floats moved in a general direction corresponding to the
ultant of the various winds and at an average rate of 6.2 miles
day.

he United States engineer office at Milwaukee has from time to
e determined the littoral currents of Lake Michigan off the harbors
hat district. These observations indicate that on the Wisconsin
re a northerly wind is accompanied by a southerly littoral surface
, and with a southerly wind the tendency is to reverse the flow.
Racine a tendency to an offshore current from westerly winds
observed. By subsurface floats the littoral current was observed
lepths of 10 feet.

A set of observations made by the Grand Rapids engineer offic during the summer of 1897 demonstrated that the littoral currents o the Michigan shore varied with the winds, but at Ludington an Frankfort, due to the projecting points north and south of thes localities, a perceptible eddy action was observed.

As it has been asserted that the movement of sand along the shor of Lake Michigan was indicative that there were pronounced current in the lake, this subject was investigated, the piers constructed the various harbors affording a means of determining the accurac of the statement. An examination of the accumulation of san against the piers extending into the lake shows that while there is movement of sand in both directions, the greatest drift of sand usually found to the north of the harbors at the southerly end of th lake on both the Wisconsin and Michigan shores. This action is n as clearly marked at the northern harbors, but there is a great drift from the south in several instances. The influence of large sa points like Point Au Sable and Point Betsie is also shown in t neighboring harbors. It appears probable that the movement sand along the shore results from wave action rather than curren and that the excess of sand moving in a southerly direction in t southern end of the lake is caused by the greater reach of wav caused by gales from a northerly direction than by those blowi from a southerly quadrant.

The conclusions from these investigations may be summarized follows:

TEMPERATURE.

During the months of January and February the surface tempe tures of all the Lakes fall to about 32° F. and then gradually rise a maximum in July and August which varies from year to ye This maximum is affected—

First. By the latitude of the station. In Lake Michigan, Chicago, the maximum monthly mean during the period of obser tions was 68.3° F.; at White Shoal Light, 65.9° F. In Lake Hur at Light Vessel No. 61, off Fort Gratiot, 68.8° F.; at Poe Lightsh 63.2° F.

Second. By the depth of water in the vicinity, being cooler as depth increases. The observations of the Lake Survey show t the maximum monthly mean in Lake Erie at Toledo was 77.4° at Horse Shoe Reef, off Buffalo, 73.4° F. In Lake Huron, at Cha Island, Saginaw Bay, 75.2° F.; at Light Vessel No. 61, off F Gratiot, 72.5° F. In Lake Michigan, Eleven Foot Shoal, north of Green Bay, 69.7° F.; Lansing Shoal, 66.6° F.

Third. By the direction of the prevailing winds. At Milwau the mean temperature during the month of July, 1911, was 64.1° with the prevailing winds from the west; at Grand Haven, on opposite side of the lake, 71.8° F. In September, when the wi had a more easterly component, the mean temperature of the wa at Grand Haven was 57.3° F. and at Milwaukee 62.9° F.

At any given locality surface temperatures are very varia changes as great as 10° being liable to occur in summer wi a few hours. At any locality near the shore there is a mar tendency for the surface water to be warmer when the wind is bl ing on shore than when it is blowing from the land. This is part ly noticeable in the log of the steamer *Hancock* for August 21, 22, d 23. In the afternoon of August 21, before entering harbor of uce Mines, with the wind from the southeast, the surface tempera- re of the water in the north channel was 64° F. In the morning leaving the harbor a temperature of 53° was observed, the wind en blowing from the northwest. As the vessel crossed the channel d approached Cockburn Island the water gradually acquired a mperature of 64°. After passing through Mississauga Straits it ldenly fell to 55°, and then gradually rose to 65° off Southampton, the Canadian shore of Lake Huron.

The mean surface temperature of the water flowing through the aits of Mackinac was slightly less than at the nearest lighthouses Lake Michigan and Lake Huron, being during the period of observa- ns at that locality 59.5° at White Shoal Light, 58.6° at Mackinac and, and 62.1° at Poe Reef Light. The mean temperature of the cago River during the period of the observations averaged 6° less n the surface temperatures of the lake at the entrance to the river. e surface temperature of the water of St. Marys River increased an average 2° during its passage from Sault Ste. Marie to Sailors campment, a distance of 18 miles, and at that locality was about warmer than the surface waters at Spectacle Reef, Lake Huron.

n Lake Superior at great depths the temperature appears to nain at 39° F. the entire year. In Lakes Michigan and Huron at eths greater than 100 feet it remains below 50° during the warmest nths. In the rivers forming the outlets to the lakes, due to the id current and consequent mixing of the waters, the observations Detroit show that there is little difference in temperature between water flowing on the surface and at the bottom. In the Straits Mackinac at a depth of 100 feet the water was about 10° warmer n at corresponding depths in Lakes Michigan and Huron.

t the time the observations were made the temperature of the air warmest at Milwaukee and coldest at White Shoal Light, the rage air temperature at Milwaukee being 1° warmer than at cago, 3.4° than at Grand Haven, and 10.2° than at White Shoal nt. But it is to be noted that White Shoal Light is at a con- rable distance from land, so that its air temperatures are affected ake influences whatever the direction of the wind.

WINDS.

he most noticeable characteristic of the winds is their extreme iability both in force and direction during the period of the ob- rations. There is, however, a decidedly easterly component to the l at Milwaukee and Chicago, and a westerly component at Grand en and White Shoal Light. This is particularly apparent when the l is light, though some diversion is observed even in strong winds is due to the influence of the lake on the air passing over it. The rvations were taken at noon when the sun's rays are producing maximum effect. The soil having much less capacity to absorb than the water, the air over the land becomes warmer and lighter the air over the lake and there is a current from the latter to the er to restore the equilibrium. After sunset in the summer a n flow from the land is observed.

xcept at Milwaukee a greater southern component to the winds observed than northern.

LAKE LEVELS.

The rapid changes which occur at a given locality in the level of t lake are shown in the diagrams of lake levels appended. These servations were so taken as to eliminate wave action, but they s show a continuous fluctuation in level, and constant change fr place to place of the point of highest or lowest elevation. A co parison of lake levels with lake temperatures shows that during months of June, July, and August, at Chicago, Milwaukee, and Gra Rapids, the 10-day period of the month that the lake has the high level corresponds with the period when the surface temperature is greatest. During September this condition is not so apparent. comparison of the temperatures at White Shoal Light with the near automatic gauge at Mackinac shows a directly opposite tenden The warmest temperature at White Shoal Light during any sum month corresponds to the lowest level of the Mackinac gauge. Th stations while at approximately the same latitude are on oppo sides of the lake.

LAKE CURRENTS.

Based on similar data the Weather Bureau and the Steamb Inspection Service have advanced diametrically opposite theorie the movement of lake waters. According to one theory, during summer months there is a more or less clearly defined surface cur in Lake Michigan which flows in a southerly direction along the consin shore, thence curves to the eastward in the vicinity of Chic and flows northerly along the Michigan shore, completing its cir in the northerly end of the lake by a flow to the west. There are certain currents branching as eddies from this main current, the marked of which are in the vicinity of Milwaukee and Beaver Isl According to the other theory, the surface currents move in stra lines corresponding to the resultants of the various winds blo over the lake at the time of observation.

Both theories were deduced by throwing bottles from vessel known localities and noting the places they were recovered. observations have the fatal defect that they show only two p in the path of the float, that from which it starts and that where found. The Weather Bureau has assumed that by repeating observations a large number of times numerous other points of curve would be discovered, but this will only be true when the is blowing with some uniformity. With conditions consta changing, this process of reasoning merely shows the facts obse are not incompatible with the theory advanced. The truth of theory is not proved, but merely its plausibility. If some theory more satisfactorily accounts for the conditions observed whole process of reasoning is destroyed.

The Weather Bureau lays some stress on the bottles dropped the steamer *Atlanta* on its trips from Chicago to Grand Have 1894 and the assumed paths of these floats are plotted on its c These bottles were thrown overboard on June 20, June 29, and Ju and the assumption appears to have been made that bottles p in the water on June 24 and July 1, farther north than those of 20, and recovered on the Michigan shore at points farther s proves a curvilinear motion of the floats. The following is a r the direction of the winds at Grand Haven during the time the ts were in the water, derived from the records of the Grand pids United States engineer office:

JUNE, 1894.

Date.	Maximum force.	Direction.
20	12	SW.
21	18	SW.
22	18	SW.
23	16	SW.
24	24	SW.
25	18	SW.
26	23	SW.
27	12	SW.
28	20	SW.
29	14	SW.
30	12	SW.

JULY, 1894.

1	24	SE.
2	20	NW.
3	16	NW.
4	24	NW.
5	18	SW.
6	25	NW.
7	16	NW.
8	18	NW.
9	14	SW.
10	17	SW.
11	20	SW.
12	27	SW.
13	21	NW.
14	12	W.
15	16	SW.
16	16	SW.
17	11	NW.
18	12	WNW.
19	18	SW.
20	18	N.

ie bottles dropped from the *Atlanta* on June 20 were, therefore, sed to a wind blowing constantly from the southwest for 10 days. rding to Mr. Meno's theory that lake currents flow in the direcof the wind at the rate of about 6 miles per day the floats would moved to the vicinity of Grand Haven by June 30. The first discovered on June 29 and the last July 16; five of the six in a few miles of Grand Haven. The three bottles thrown overd from the *Atlanta* on July 1 were exposed to winds with a southcomponent for four days and winds with a northerly component x days, and would have moved in a westerly direction according e same theory, and would have landed, as they, did south of the h of the Kalamazoo River. Those floated on June 24 were sed to winds with a southerly component seven times and northcomponent three times, and drifted to shore between Grand n and Saugatuck. It is not necessary to assume that because ottles dropped on July 1 farther north than those of June 20 found farther south on the Michigan shore, they all moved in linear paths. The change in the direction of the winds between 20 and July 1 satisfactorily accounts for the change in the locapf the stranding of the floats.

nore logical and satisfactory method of determining the direction e currents of the lakes is by simultaneously observing them at numerous localities. Observations for this purpose were made da during the months of July, August, and September, 1911, off Chicag Milwaukee, Grand Haven, and White Shoal Lighthouse.

The results are tabulated in Table I.

These observations show that when a strong wind is blowing t direction of the currents at all localities is in the direction of the wi When, however, the wind diminishes in intensity but continues in t same direction, the current may flow in a direction opposite to t wind. At Chicago, during 33 days a northerly current was record during 41 a southerly, and during 18 days the current was inapp ciable or moving on or off shore. At Grand Haven, the results w a northerly current during 44 days, a southerly during 32, and on off shore during the 16 days.

For the currents described by the Weather Bureau to obtain i necessary for the currents at Chicago to flow in an opposite direct from those at Grand Haven. The record shows 50 days in which currents coincided in direction at Chicago and Grand Haven, 12 d in which they flowed in opposite directions, and 30 days in whic northerly or southerly current at one locality was accompanied an off or on shore current at the other. The observations dem strated that there are no fixed surface currents in Lake Michigan, that the currents change in direction and intensity with the wi and are extremely variable, particularly during the summer mon The currents of the lake, instead of flowing south on one side north on the other, as assumed by the Weather Bureau, hav motion on the surface in the direction the wind is blowing. water is also raised by the wind on one side of the lake and lowe on the other, and this disturbance of the equilibrium causes a ret flow of water along the lake bottom. There is thus a circulatio the water from top to bottom on one side of the lake and from bot to surface on the other, and the continual change in direction of wind tends to continually change the location at which this surface flow occurs and causes a more or less complete mixing o waters.

When a current of air passes over a body of water the surfac the water either absorbs heat from the air or radiates it, dependen the relative temperatures of the two media. If the water is co than the air but above 39° F. (its state of maximum density), upper stratum absorbs heat, expands, and becomes lighter than lower layers of water, while the lower stratum of air becomes co than upper layers, and therefore denser. Under these conditions passage of heat from air to water occurs slowly, unless the air water be agitated so as to bring fresh particles in contact, as is case when the air currents have sufficient force to produce action on the water. If the wind has sufficient force not onl produce wave action but to raise the water surface on one side o basin toward which it is blowing, not only are fresh particles bro in contact with the air, but the difference in elevation on opp sides of the basin causes an upward motion of the water where head is the least, which continuously brings the lower and c layers of water to the surface to absorb heat from the air. The e of water on the temperature of the air passing over it is theref function of the strength of the winds and of the area and depth o lake.

ake Michigan has an area of over 22,000 square miles. Its atest length is 307 miles, its width 118 miles, and maximum depth feet, so that it exposes an enormous water surface to the action vinds, and its depth gives an immense volume of water to absorb adiate heat. It is also connected to Lake Huron, which also has area exceeding 22,000 square miles and a maximum depth of 750 , by a broad and deep channel through which not unfrequently e is a flow of over 2,000,000 cubic feet per second, so that there be no material diminution of the volume of one lake without a esponding reduction in that of the other, and any material change emperature in one lake will be transmitted to the other.

hese, rather than lake surface currents, are the factors which ct the climate of the Lake States, and the principal effect upon the ate which would result from the diversion of water through the ago Drainage Canal would be that due to the extent that it dimind the volume or area of the lake, and thus reduced its capacity to rb or radiate heat. A diversion of 10,000 second-feet will reduce evel of Lake Michigan about 6 inches. The reduction in volume rea of a lake 870 feet deep and having an area exceeding 22,000 re miles by a reduction of level of 6 inches is inappreciable.

ut though while the observations were being taken the winds were ariable both in intensity and direction as to insure an intimate ng of surface and subsurface waters, yet the records of the ther Bureau show that occasionally, particularly in the spring and there are prevailing winds of considerable constancy of direction. e such winds are blowing there is a surface current of correspondonstancy, not south on one shore and north on the other, but nding over the entire area of the lake. Such winds move immense es of water for long distances and, except when nearing the shore, out that intimate mingling of surface and subsurface waters, n is so beneficial to the climate. This action is illustrated by the ng of ice fields over the surface of the lake in winter and the se cold which locally results therefrom.

ile the flow through the Straits of Mackinac is very variable, in direction and amount, dependent on the direction and force wind, and at times equals 2,000,000 second-feet, there must be dual discharge into Lake Huron from Lake Michigan of about 0 second-feet. Also, while the winds cause a continual oscillan the flow of water in Lake Michigan, its resultant flow must be d its outlet. The area of the cross-section of the lake is so that such a discharge would cause a uniform movement of its s of about 25 feet per day, or 1.6 miles per year. A discharge 000 cubic feet per second through the Chicago Drainage Canal reduce this flow to the rate of about 1.5 miles per year.

be assumed that there is a uniform mixing of the waters from e to bottom of the lake, a particle of water starting at its southd would require from 190 to 220 years to reach the Straits of nac, it would yearly change its temperature from 32° to a num dependent on the latitude. A change of latitude of twoof a mile a year will not produce an appreciable effect on the rature of the water. If, on the other hand, it be assumed that is a strong wind blowing from the south while the particle of is making its journey, the observations of Mr. Meno indicate would move on the surface of the water at the rate of about

6 miles per day and would require about 50 days to travel the leng
of the lake. If it be assumed that this surface current has only
depth of 10 feet (at Racine the current was observed at that dept
a flow of 10,000 cubic feet in the opposite direction would retard t
northward movement of this particle of water about eight hou
The effect on the temperature of the water by such a retardati
would not be measurable. These are the extreme limits of possi
lake action and illustrate the insignificance of the lake discharge wh
compared with the movements which take place in the lake its
during every storm.

The observations also show that the temperature of the water
charging through the Chicago Drainage Canal is affected by the di
tion and intensity of the winds; that during summer months the m
temperature of the surface water of Lake Michigan at Chicag
about the same as that of Lake Huron at its mouth; and that dur
the same period the discharge from Lake Superior through St. Ma
River into Lake Huron is not only warmer than the waters of t
lake, but also than that of the flow from Lake Michigan i
Huron through the Straits of Mackinac.

In conclusion it may be stated that the effect on the clima
Lake States, caused by diverting 10,000 second-feet of water
the Chicago Drainage Canal, whether theoretically beneficial o
jurious, would be infinitesimal; i. e., incapable of being measure
the most delicate instruments.

C. McD. Townsend,
Colonel, Corps of Enginee

TABLE 1.

DIRECTION OF WINDS.

1911.	Chicago.					Milwaukee.					Grand Haven.					White Shoal		
	Easterly.	Westerly.	Northerly.	Southerly.	Calm or variable.	Easterly.	Westerly.	Northerly.	Southerly.	Calm or variable.	Easterly.	Westerly.	Northerly.	Southerly.	Calm or variable.	Easterly.	Westerly.	Northerly.
June (20 days)	8	6	7	8	1	9	7	10	3	2	3	10	5	10	1	6	10	3
July	13	13	7	21	....	16	14	11	10	1	1	19	11	18	....	1	25	6
August	19	9	11	16	1	19	9	11	17	1	6	19	9	12	1	5	22	10
September	17	9	13	9	2	18	9	10	7	2	9	12	10	16	....	8	19	12

FORCE OF WINDS.

1911.	Chicago.				Milwaukee.				Grand Haven.				White S Ligh	
	Strong.	Moderate.	Light.	Calm.	Strong.	Moderate.	Light.	Calm.	Strong.	Moderate.	Light.	Calm.	Strong.	Moderate.
June (20 days)	5	14	....	1	5	5	10	....	7	....	12	1	6	3
July	5	23	3	....	12	14	5	....	15	....	16	....	15	4
August	5	16	10	....	11	12	8	....	16	....	24	1	17	....
September	10	15	3	2	19	2	9	....	9	....	20	1	12	2

War Department.

LAKE MICHIGAN.

Automatic Gage Readings at Chicago (.........), Milwaukee (-·-·-), Grand Haven (Staff Read) and Mackinaw (——) during the Month of June 1911.

Corps of Engineers, U.S. Army.

Appendix C, Plate 1.

LAKE HURON.

Automatic Gage Readings at Mackinaw (——) Harbor Beach (-·-·-) and Port Huron (.........) during the Month of June 1911.

Note: All Elevations refer to Mean Tide at N.Y.

PETERS CO. WASHINGTON, D. C

House Doc. No. 762; 63d Cong., 2d Sess.

War Department.

Corps of Engineers, U.S. Army.

Appendix C, Plate 2.

LAKE MICHIGAN

Automatic Gage Readings at Chicago (..........), Milwaukee (—•—•—) Grand Haven (Staff Read) and Mackinaw (———) during the Month of July 1911.

LAKE HURON

Automatic Gage Readings at Mackinaw (———), Harbor Beach (—•—•—) and Port Huron (..........) during the Month of July 1911.

Note: All Elevations refer to Mean Tide at N.Y.

House Doc. No. 762; 63d Cong., 2d Sess.

War Department.

Corps of Engineers. U.S. Army.

Appendix C, Plate 3

LAKE MICHIGAN

Automatic Gage Readings at Chicago (..........), Milwaukee (—·—·—), Grand Haven (Staff Rec.) and Mackinaw (———) during the Month of August 1911.

LAKE HURON

Automatic Gage Readings at Mackinaw (———), Harbor Beach (—·—·—) and Port Huron (..........) during the Month of August 1911.

Note: All Elevations refer to Mean Tide at N.Y.

House Doc. No. 762; 63d Cong., 2d Sess.

War Department.

Corps of Engineers. U.S. Army.

Appendix C, Plate 4

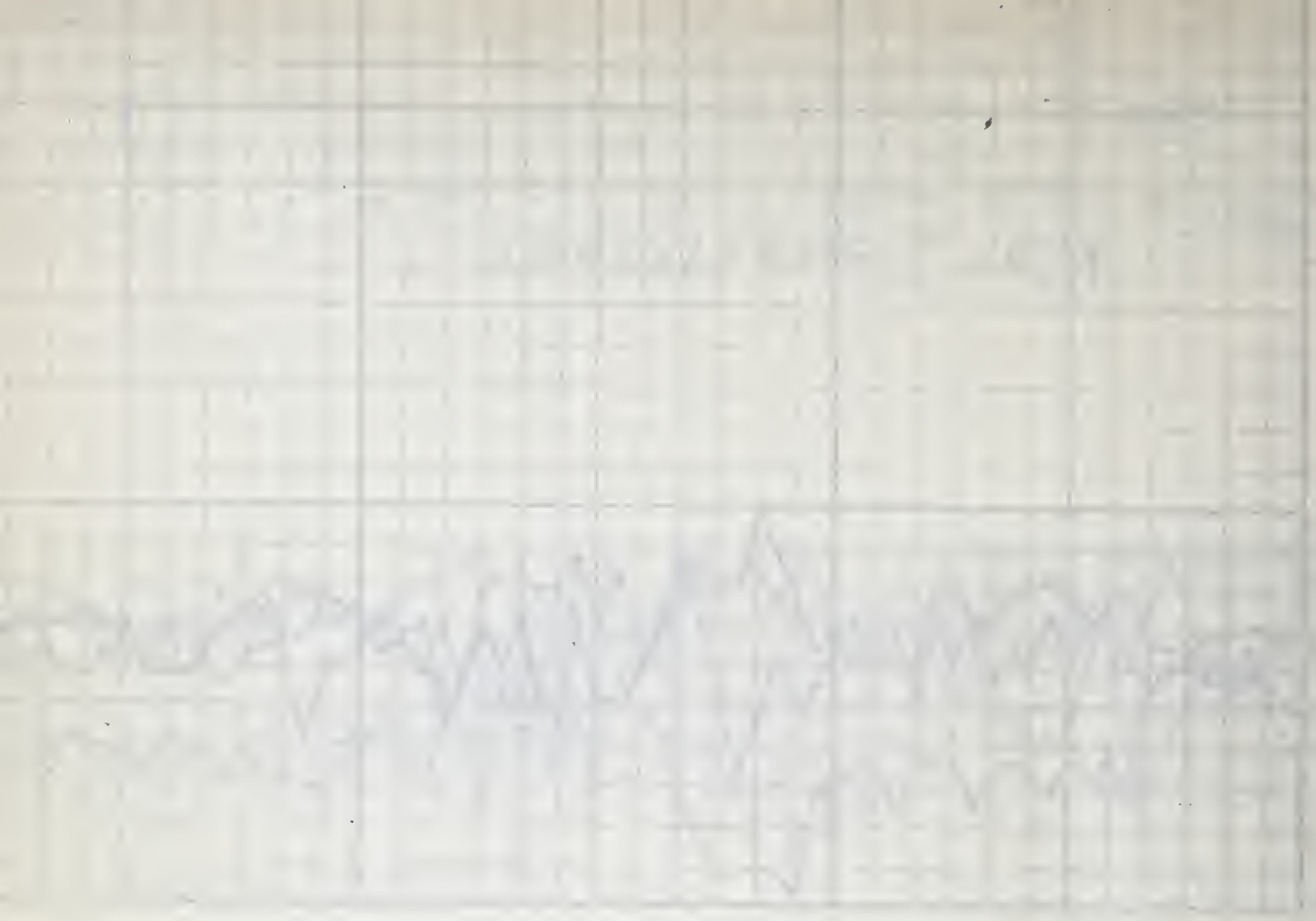
LAKE MICHIGAN

Automatic Gage Readings at Chicago (.........), Milwaukee (-.-.-), Grand Haven (Staff Read.) and Mackinaw (——) during the Month of September, 1911.

LAKE HURON

Automatic Gage Readings at Mackinaw (——), Harbor Beach (-.-.-) and Port Huron (.........) during the Month of September, 1911.

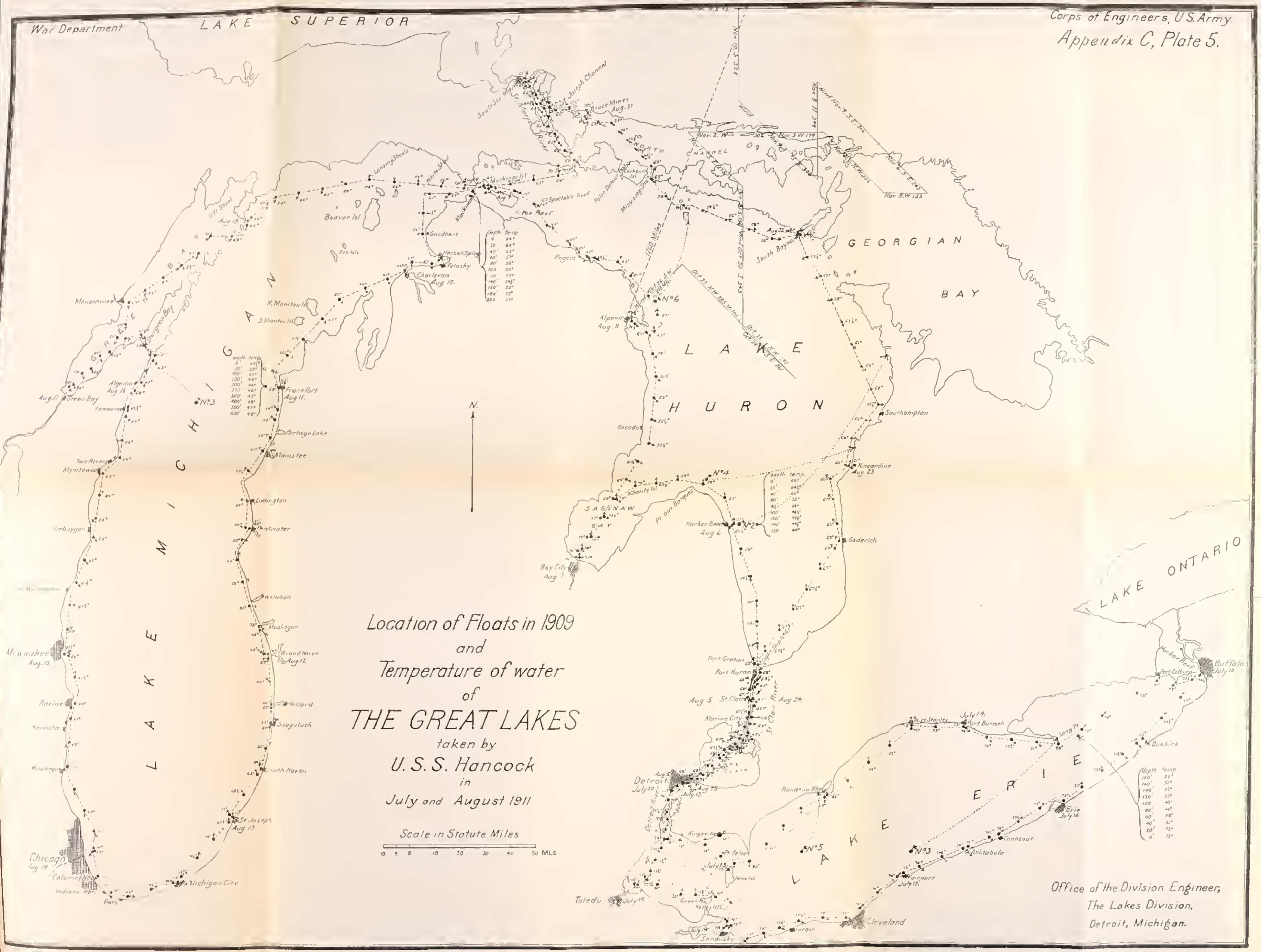
House Doc. No. 762; 63d Cong., 2d Sess.



War Department

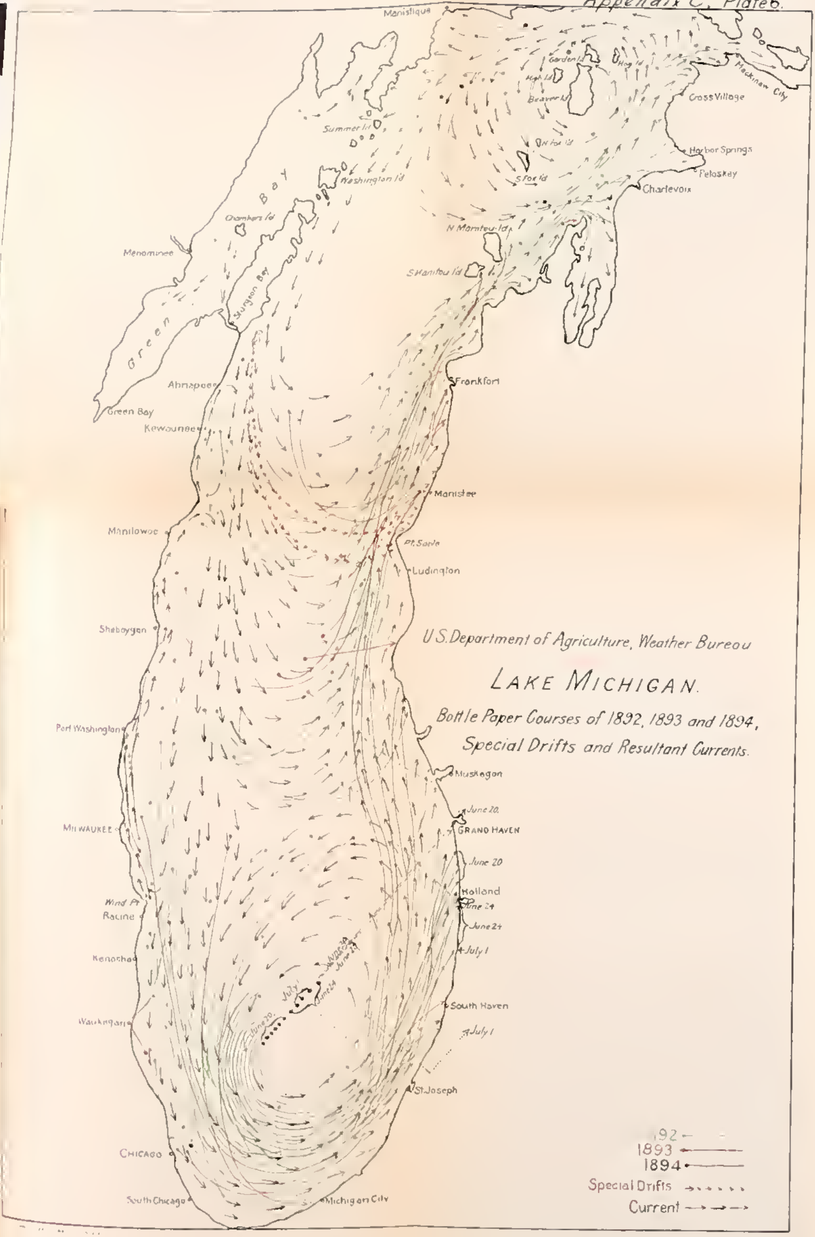
Corps of Engineers, U.S. Army.

Appendix C, Plate 5.



Location of Floats in 1909 and Temperature of water of THE GREAT LAKES taken by U.S.S. Hancock in July and August 1911

Office of the Division Engineer,
The Lakes Division,
Detroit, Michigan.



U.S. Department of Agriculture, Weather Bureau

LAKE MICHIGAN.

Bottle Paper Courses of 1892, 1893 and 1894, Special Drifts and Resultant Currents.

TABLE 1—Continued.

DIRECTION OF CURRENTS.

1911.	Chicago.			Milwaukee.			Grand Haven.			White Shoal Light.		
	Northerly.	Southerly.	On or off shore.	Easterly.	Westerly.	On or off shore.	Northerly.	Southerly.	On or off shore.	Northeasterly.	Southwesterly.	On or off shore.
July	15	13	3	14	12	5	15	13	3	20	4	7
August	7	15	9	13	17	1	13	11	7	15	13	3
September	11	13	6	10	18	3	16	8	6	12	14	4

TEMPERATURES.

[In degrees Fahrenheit.]

1911.	Chicago.		Milwaukee.		Grand Haven.		White Shoal Light.		Chicago River.		St. Marys River.	
											Sault Ste. Marie.	Sailors Encampment.
	Water.	Air.	Water.	Air.	Water.	Air.	Water.	Air.	Water.	Air.	Water.	Water.
June (20 days)	66.1	73.6	62.2	74.6	63.6	72.7	56.3	62.0	55.2	78.7	51.6	54.0
July	68.3	76.1	64.1	78.1	71.8	75.7	63.3	67.7	64.3	75.2	59.5	61.2
August	67.8	75.3	62.2	74.7	65.2	72.3	65.9	68.1	68.8	77.5	60.6	62.8
September	67.3	68.1	62.9	69.7	57.3	62.8	60.3	58.8	66.1	72.4	57.6	58.6

SUBSURFACE TEMPERATURES.

Lake Michigan off Frankfort.		Straits of Mackinac.		Lake Huron off Harbor Beach.		Detroit River.		Lake Erie off Long Point.	
Aug. 11, 1911.		Aug. 9, 1911.		Aug. 5, 1911.		Aug. 25, 1911.		July 14, 1911.	
Depth.	Temperature.	Depth.	Temperature.	Depth.	Temperature.	Depth.	Temperature.	Depth.	Temperature.
Feet.	*°F.*	*Feet.*	*°F.*	*Feet.*	*°F.*	*Feet.*	*°F.*	*Feet.*	*°F.*
Surface.	64½	Surface.	64	Surface.	68	Surface.	68½	Surface.	72
50	58	20	64	20	64½	20	68½	20	72
100	47	40	62	40	60	40	68½	40	62
150	46	60	57	60	55	....	....	60	48
200	46	80	56	80	54	....	....	80	46
250	46	100	55	100	46½	....	....	100	45
300	45	120	55	120	45½	....	....	120	53
400	48	140	54½	140	44½	....	....	140	52
500	47	160	53	150	44	....	....	160	51
600	48	180	53	....	....	....	....	180	54
....	....	200	53	....	....	....	....	....	....

MEAN ELEVATIONS OF LAKE LEVEL AT 12 M.

1911.	June—		July—			August—			September—		
	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–30
Chicago	579.89	579.94	579.89	579.87	579.61	579.75	579.69	579.74	579.52	579.59	579.69
Milwaukee	579.97	580.03	580.00	579.90	579.77	579.83	579.88	579.75	579.80	579.60	579.78
Grand Haven	580.03	580.15	580.01	579.95	579.84	580.06	579.95	579.83	......	......	......
Mackinac	580.07	579.97	580.04	579.99	579.91	579.92	579.85	579.75	579.62	579.66	579.50
Harbor Beach	580.06	579.97	579.95	579.96	579.90	579.81	579.92	579.83	579.60	579.61	579.54
Port Huron	579.31	579.25	579.23	579.19	579.15	579.08	579.20	579.13	578.91	578.92	578.84

TABLE 2.—*Mean surface temperatures of the Great Lakes.*

[In degrees Fahrenheit.]

LAKE SUPERIOR.

Month.	Devils Island Lighthouse.		Passage Island.		Stannard Rock Lighthouse.	
	1905	1906	1905	1906	1905	1906
January	......	......	......	......	......	......
February	......	......	......	......	......	......
March	......	......	......	......	......	......
April	36.1	36.2	33.0	35.3	34.4	34.9
May	40.1	39.4	36.4	37.1	35.8	36.3
June	47.2	46.3	39.7	39.8	38.3	38.3
July	56.4	60.6	44.4	44.9	42.2	47.6
August	61.3	63.0	54.8	55.9	51.4	54.1
September	56.4	59.0	51.6	52.9	50.3	53.0
October	50.0	51.4	47.5	46.5	48.0	47.1
November	42.2	41.5	40.5	39.4	41.8	42.2
December	36.3	36.7	37.1	35.8	......	......

LAKE MICHIGAN.

Month.	Milwaukee Breakwater.			Grand Haven Lighthouse.			Eleven-Foot Shoal Lighthouse.			Lansing Shoal Lighthouse.		
	1904	1905	1906	1904	1905	1906	1904	1905	1906	1904	1905	1906
January	......	......	32.8	......	......	......	......	......	......	......	......	......
February	......	......	32.5	......	......	......	......	......	......	......	......	......
March	......	34.2	33.4	......	......	33.8	......	......	......	......	......	......
April	......	40.1	40.7	......	42.8	43.8	......	36.0	38.0	......	......	36.8
May	......	46.4	47.4	......	51.1	51.5	......	41.8	44.3	......	39.6	40.8
June	......	53.9	53.1	......	57.9	59.0	......	53.9	56.1	......	50.1	54.3
July	......	61.4	61.9	......	62.7	64.3	......	62.5	66.9	......	59.5	65.5
August	......	67.0	68.5	......	67.4	70.5	......	66.9	69.7	......	65.3	66.6
September	......	56.8	58.6	......	65.5	64.6	......	62.8	63.5	......	62.2	62.7
October	......	45.0	53.3	......	55.8	51.6	......	55.6	54.5	......	55.3	52.9
November	43.1	39.6	42.7	42.3	41.8	44.2	......	43.8	44.1	44.7	44.3	43.6
December	34.4	34.2	36.4	33.2	34.0	33.9	......	38.0	36.9	40.0	......	37.5

LAKE ST. CLAIR AND LAKE ERIE.

Month.	Grossepoint Light Vessel.		Toledo Harbor Light Vessel.				South East Shoal Lightship.		Horseshoe Reef.				
	1905	1906	1904	1905	1906	1907	1905	1906	1904	1905	1906	1907	1908
January	......	......	......	32.0	......	32.3	......	......	......	......	......	......	......
February	......	......	......	32.0	......	32.0	......	......	......	......	......	......	......
March	......	......	......	......	......	36.7	......	......	......	......	......	......	......
April	41.0	42.2	......	43.7	43.7	40.9	......	41.6	......	32.0	34.9	......	33.6
May	51.5	50.9	......	57.5	57.0	50.6	......	51.2	......	45.0	46.9	......	45.7
June	62.4	62.5	......	69.9	66.9	63.3	70.3	65.0	......	60.5	59.0	67.3	65.1
July	68.9	70.5	......	74.4	75.0	73.0	73.5	72.3	......	69.6	69.4	69.1	71.3
August	70.6	74.2	......	73.2	77.4	72.1	73.4	76.2	......	69.8	73.4	69.8	70.9
September	66.1	69.7	......	68.2	72.4	67.8	68.7	72.2	......	66.8	69.5	66.8	66.5
October	56.5	55.4	......	56.8	53.5	53.3	60.1	58.2	......	59.2	59.1	55.9	58.8
November	42.2	43.4	40.3	40.3	43.2	41.7	43.4	46.8	43.9	45.2	46.3	45.5	45.4
December	35.9	34.6	32.2	33.6	33.9	34.1	35.6	38.4	36.2	38.3	35.9	36.9	37.7

TABLE 2.—*Mean surface temperatures of the Great Lakes*—Continued.

LAKE HURON.

Month.	Spectacle Reef Lightship.		Charity Island Lighthouse.		Lake Huron Light Vessel No. 61.	
	1905	1906	1905	1906	1905	1906
January						
February						
March						
April	34.8	35.0	48.4	46.4	38.3	39.8
May	37.0	38.3	54.6	54.6	45.4	46.6
June	47.6	51.6	67.1	67.5	59.8	58.8
July	59.5	64.4	72.4	73.1	66.1	68.5
August	65.0	66.7	72.7	75.2	67.7	72.5
September	62.7	61.7	67.1	70.0	65.9	70.0
October	50.3	49.7	53.3	55.3	58.9	57.3
November	41.3	42.6	41.9	42.6	46.5	45.7
December	40.0	38.4	36.0		39.4	37.3

LAKE ONTARIO.

Month.	Charlotte Lighthouse.			Galloo Island Lighthouse.		
	1904	1905	1906	1904	1905	1906
January		32.3				
February		42.3				
March		48.5	34.6			
April		42.3	42.9		37.6	40.2
May		48.5	50.3		45.6	49.3
June		59.0	58.5		56.4	60.2
July		64.5	57.2		66.5	70.3
August		64.9	61.5		68.7	72.9
September		62.6	67.2		65.4	65.4
October		55.3	54.0		58.2	54.3
November	40.9	40.0	42.3	40.5	45.8	41.1
December	32.4	33.9	33.8	32.4	37.6	32.0

APPENDIX C (Part 2).

Observations of air and water surface temperatures, wind, and current.

RUSH STREET BRIDGE, CHICAGO RIVER.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 11[1]			W		
June 12	69	57	W		
June 13	71	59	N		
June 14	69	62	N		
June 15	76	63	N		
June 16	66	63	E		
June 17			NE		
June 18[1]			N		
June 19	71	66	NE		
June 20	77	66	N		
Average	71.3	62.3			

[1] Sunday

Observations of air and water surface temperatures, wind, and current—Continued.

RUSH STREET BRIDGE, CHICAGO RIVER—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	78	69	E		
June 22	85	70	W		
June 23	88	69	S		
June 24	78	69	SE		
June 25[1]			SW		
June 26	76	66	SW		
June 27	74	61	W		
June 28	68	60	NE		
June 29	71	65	E		
June 30	81	67	SW		
Average	77.7	66.2			
July 1	89	67	SW		
July 2[1]			SW		
July 3	94	65	SW		
July 4 (holiday)			SW		
July 5	96	70	SW		
July 6	74	65	N		
July 7	76	70	NE		
July 8	83	73	SE		
July 9[1]			S		
July 10	83	73	SW		
Average	85.0	69.0			
July 11	82	73	N		
July 12	75	73	NE		
July 13	79	72	NE		
July 14	71	73	NE		
July 15	86	73	SW		
July 16[1]			NE		
July 17	70	70	E		
July 18	80	70	SW		
July 19	74	90	SW		
July 20	72	70	NE		
Average	76.6	73.8			
July 21	71	70	NE		
July 22	74	70	E		
July 23[1]			S		
July 24	64	62	W		
July 25	64	62	W		
July 26	67	62.5	E		
July 27	77	62	S		
July 28	75	61	E		
July 29			E		
July 30[1]			S		
July 31	76	60	SE		
Average	71.0	63.7			
Aug. 1	74	59	W		
Aug. 2	70	59	NE		
Aug. 3	71	63	NE		
Aug. 4	75	64	E		
Aug. 5			E		
Aug. 6[1]			NE		
Aug. 7	86	69	SW		
Aug. 8			NE		
Aug. 9	86	66	SW		
Aug. 10	76	64	NE		
Average	76.9	63.4			
Aug. 11	69	66	N		
Aug. 12	68	66	SW		
Aug. 13[1]			NW		
Aug. 14	83	69	SW		
Aug. 15	75	69	NE		
Aug. 16	85	71	SW		
Aug. 17	77	70	N		
Aug. 18	72	70	NE		
Aug. 19	70	70	NE		
Aug. 20[1]					
Average	74.9	68.9			

[1] Sunday.

Observations of air and water surface temperatures, wind, and current—Continued.

RUSH STREET BRIDGE, CHICAGO RIVER—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	80	71	S.		
Aug. 22	68	68	N		
Aug. 23	68	66	NE		
Aug. 24	65	64	E		
Aug. 25	70	64	NE		
Aug. 26	72	67	E		
Aug. 27[1]					
Aug. 28	70	66	N		
Aug. 29	63	64	NE		
Aug. 30	65	65	E		
Aug. 31	73	66	S.		
Average	69.4	66.1			
Sept. 1	76	66	NE		
Sept. 2			W		
Sept. 3[1]			NE		
Sept. 4[2]			E		
Sept. 5	73	68	SE.		
Sept. 6	68	67	NE		
Sept. 7	70	67	NE		
Sept. 8	66	67	NE		
Sept. 9	67	67	E		
Sept. 10[1]			SE.		
Average	70.0	67.0			
Sept. 11	76	69	SW		
Sept. 12	63	66	NE		
Sept. 13	65	65	NE		
Sept. 14	72	66	S.		
Sept. 15	72	67	SE.		
Sept. 16			SW		
Sept. 17[1]			SE.		
Sept. 18	78	70	SW		
Sept. 19	67	67	N		
Sept. 20	67	66	E		
Average	70.0	67.0			
Sept. 21	65	66	W		
Sept. 22	67	66	SE.		
Sept. 23	71	66	SW		
Sept. 24[1]			N		
Sept. 25	65	65	W		
Sept. 26	59	62	E		
Sept. 27	73	65	W		
Sept. 28	63	64	SE.		
Sept. 29	64	63	W		
Sept. 30	56	62	SE.		
Average	64.8	64.3			

CHICAGO HARBOR LIGHT, LAKE MICHIGAN.

1911.					
June 11	76	60	WNW	Moderate	
June 12	68	58	WNW	do	
June 13	68	60	N	do	
June 14	74	63	N	do	
June 15	74	63	Calm		
June 16	62	63	SE	Strong	
June 17	63	64	E	do	
June 18	78	65	NE	Moderate	
June 19	78	68	WSW	do	
June 20	72	68	NW	do	
Average	71.3	63.2			

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[1] Sunday.

[2] Labor Day.

Observations of air and water surface temperatures, wind, and current—Continued.

CHICAGO HARBOR LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	76	68	SW	Moderate	
June 22	85	74	SE	do	
June 23	84	72	SSE	do	
June 24	72	70	SSE	do	
June 25	74	69	SE	High	
June 26	82	71	SSE	Strong	
June 27	72	65	WNW	do	
June 28	68	67	NE	Moderate	
June 29	70	66	E	do	
June 30	76	68	SE	do	
Average	75.9	69.0			
July 1	86	67	S	Moderate	
July 2	86	70	SW	do	
July 3	91	70	SW	do	
July 4	94	76	SE	do	
July 5	96	76	SW	do	
July 6	72	67	N	Fresh	
July 7	80	71	SE	Moderate	
July 8	78	70	S	do	
July 9	83	74	SSW	do	
July 10	84	74	S to W	do	
Average	85.0	71.5			
July 11	82	76	SW	Moderate	
July 12	72	72	NE	do	
July 13	76	67	E	do	
July 14	74	67	NE	do	
July 15	74	69	SW	Fresh	
July 16	70	67	NNE	do	
July 17	72	70	SW	do	
July 18	78	70	SW	Light	
July 19	72	69	SW	do	
July 20	74	70	NE	Moderate	
Average	74.4	69.7			
July 21	68	63	NE	Moderate	
July 22	72	68	SE	do	
July 23	72	68	SE	do	
July 24	60	62	WNW	Gale	
July 25	64	62	NW	Moderate	
July 26	66	64	ESE	do	
July 27	70	64	ESE	do	
July 28	72	60	SW	do	
July 29	68	62	E	Light	
July 30	74	64	S	Moderate	
July 31	73	63	SE	do	
Average	69.0	63.6			
Aug. 1	73	64	SW	Moderate	N., weak.
Aug. 2	75	65	SE	do	Do.
Aug. 3	73	65	NE	Fresh	S., moderate.
Aug. 4	72	65	E	Moderate	Do.
Aug. 5	80	70	E	Light	N., weak.
Aug. 6	85	70	NE	Moderate	S., weak.
Aug. 7	84	68	SW	do	N., moderate.
Aug. 8	78	68	SE	do	Do.
Aug. 9	80	65	SW	do	Do.
Aug. 10	72	67	N	Light	Do.
Average	77.2	66.7			
Aug. 11	68	64	N	Light	S., strong.
Aug. 12	70	63	SE	Moderate	Do.
Aug. 13	70	68	SE	Light	
Aug. 14	78	72	NE	do	S., light.
Aug. 15	90	70	NE	do	
Aug. 16	82	71	SW	Moderate	N., moderate.
Aug. 17	78	71	N	Light	S., strong.
Aug. 18	75	68	NE	Fresh	Do.
Aug. 19	74	70	NE	Moderate	S., moderate.
Aug. 20	80	71	NE	do	S., light.
Average	76.5	68.8			

Observations of air and water surface temperatures, wind, and current—Continued.

CHICAGO HARBOR LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	74	71	SW	Very fresh	N., strong.
Aug. 22	73	68	N	Fresh	S., strong.
Aug. 23	68	64	NE	Moderate	Do.
Aug. 24	64	62	ESE	Fresh	N., strong.
Aug. 25	70	65	SE	Light	
Aug. 26	70	68	S	do	S., light.
Aug. 27	80	71	WNW	do	
Aug. 28	70	70	N	Moderate	S., moderate.
Aug. 29	78	70	NE	do	S., light.
Aug. 30	74	70	NE	do	S., moderate.
Aug. 31	78	68	E	do	Do.
Average	72.6	67.9			
Sept. 1	80	67	Calm		
Sept. 2	76	71	WNW	Moderate	S., moderate.
Sept. 3	74	68	E	do	
Sept. 4	70	67	ESE	do	
Sept. 5	72	70	SE	do	N., light.
Sept. 6	70	68	E	Fresh	N., moderate.
Sept. 7	70	69	E	Light	N., light.
Sept. 8	72	67	NE	Moderate	S., moderate.
Sept. 9	74	70	E	do	N., light.
Sept. 10	72	70	SW	do	Do.
Average	73.0	68.7			
Sept. 11	74	68	SW	Fresh	N., light.
Sept. 12	62	69	NE	do	S., moderate.
Sept. 13	65	68	NE	do	S., light.
Sept. 14	68	67	SE	do	N., strong.
Sept. 15	76	65	E	Light	
Sept. 16	74	68	Calm		
Sept. 17	74	70	S	Moderate	N., moderate.
Sept. 18	72	69	WNW	do	S., light.
Sept. 19	62	68	NW	Fresh	S., strong.
Sept. 20	64	69	NE	do	Do.
Average	69.1	68.1			
Sept. 21	62	67	NW	Moderate	S., moderate.
Sept. 22	64	65	SE	do	N., light.
Sept. 23	72	66	SW	do	N., moderate.
Sept. 24	68	67	N	Fresh	S., strong.
Sept. 25	59	65	NE	do	Do.
Sept. 26	58	65	NE	Moderate	S., light.
Sept. 27	64	65	NW	Light	
Sept. 28	58	63	SE	Moderate	N., light.
Sept. 29	60	64	NW	Fresh	S., strong.
Sept. 30	58	63	SE	Moderate	S., moderate.
Average	62.3	65.0			

MILWAUKEE PIERHEAD LIGHT, LAKE MICHIGAN.

1911.					
June 11	78	58	NW	Brisk	
June 12	68	54	NW	do	
June 13	71	56	N	Fresh	
June 14	74	61	E	Light	
June 15	78	62	NE	do	
June 16	64	56	NW	Moderate	
June 17	64	58	NE	do	
June 18	72	62	NE	Light	
June 19	80	64	W	do	
June 20	78	66	NE	do	
Average	72.7	59.7			

Observations of air and water surface temperatures, wind, and current—Continued.

MILWAUKEE PIERHEAD LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	80	66	SE	Light	
June 22	84	66	W	do	
June 23	90	66	W	do	
June 24	74	67	E	do	
June 25	72	66	Var	do	E.
June 26	76	66	Var	do	W., strong.
June 27	70	62	NW	Moderate	W., strong.
June 28	70	62	NE	Light	E.
June 29	72	63	SE	Moderate	W.
June 30	78	63	S	do	NW.
Average	76.6	64.7			
July 1	94	65	SW	Moderate	E.
July 2	94	62	W	do	E.
July 3	96	63	NE	do	S.
July 4	88	70	E	Light	W.
July 5	92	68	Var	do	S.
July 6	76	72	NE	Fresh	S.
July 7	74	71	NE	Moderate	E.
July 8	80	70	E	Fresh	W.
July 9	90	68	SW	do	NE.
July 10	82	71	SE	Moderate	W.
Average	86.6	68.0			
July 11	88	70	W	Fresh	E.
July 12	78	68	NW	Moderate	S.
July 13	81	64	NW	do	S.
July 14	80	67	W	do	SE.
July 15	86	68	NW	Fresh	SE.
July 16	74	65	NE	do	W.
July 17	72	67	W	Light	E.
July 18	74	68	W	Moderate	E.
July 19	74	66	ENE	do	W.
July 20	76	64	E	do	W.
Average	78.3	66.7			
July 21	76	65	SE	Moderate	N.
July 22	80	67	NE	do	W.
July 23	64	66	SE	Brisk	W.
July 24	68	60	NW	do	E.
July 25	68	56	NW	Light	E.
July 26	72	51	E	do	W.
July 27	64	54	SE	Fresh	W.
July 28	70	56	SW	do	E.
July 29	68	53	ESE	Moderate	W.
July 30	66	53	SE	Fresh	W.
July 31	68	53	SE	Moderate	E.
Average	69.5	57.6			
Aug. 1	78	57	SW	Moderate	E.
Aug. 2	76	58	SW	do	E.
Aug. 3	76	59	NE	do	W.
Aug. 4	72	58	SE	Fresh	W.
Aug. 5	80	62	SE	Moderate	W.
Aug. 6	76	61	SE	Brisk	W.
Aug. 7	72	58	SW	Moderate	E.
Aug. 8	72	58	NW	do	E.
Aug. 9	76	59	SW	do	E.
Aug. 10	64	56	NE	do	E.
Average	74.2	58.6			
Aug. 11	64	56	NE	Fresh	W.
Aug. 12	66	58	NE	Moderate	W.
Aug. 13	68	59	SE	do	E.
Aug. 14	76	67	SE	do	W.
Aug. 15	80	67	SE	do	W.
Aug. 16	82	64	WSW	Light	W.
Aug. 17	84	66	Var	do	E.
Aug. 18	80	66	NE	do	W.
Aug. 19	82	67	E	do	W.
Aug. 20	74	66	SE	Fresh	W.
Average	75.6	63.6			

Observations of air and water surface temperatures, wind, and current—Continued.

MILWAUKEE PIERHEAD LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	78	65	S	Fresh	E.
Aug. 22	66	64	N	do	S.
Aug. 23	78	64	NE	Light	E.
Aug. 24	78	65	NE	do	W.
Aug. 25	72	64	SE	do	E.
Aug. 26	72	64	ESE	Fresh	W.
Aug. 27	82	64	SW	Moderate	E.
Aug. 28	68	65	NW	Fresh	E.
Aug. 29	70	64	NE	do	W.
Aug. 30	74	64	E	do	W.
Aug. 31	78	66	SW	Light	W.
Average	74.6	64.4			
Sept. 1	76	64	SE	Fresh	W.
Sept. 2	79	67	NE	do	W.
Sept. 3	78	65	E	Moderate	W.
Sept. 4	76	66	SE	Fresh	W.
Sept. 5	78	66	S	do	E.
Sept. 6	68	64	NE	do	W.
Sept. 7	70	65	N	do	W.
Sept. 8	64	61	NE	Light	W.
Sept. 9	74	64	E	do	W.
Sept. 10	68	62	Var	do	E.
Average	73.1	64.4			
Sept. 11	74	62	SW	Fresh	E.
Sept. 12	64	62	NE	do	W.
Sept. 13	66	62	E	do	W.
Sept. 14	64	63	ESE	Brisk	W.
Sept. 15	78	62	W	Light	E.
Sept. 16	80	66	W	do	E.
Sept. 17	72	64	E	do	W.
Sept. 18	74	63	W	Moderate	E.
Sept. 19	78	66	E	Light	E.
Sept. 20	74	66	E	do	E.
Average	72.4	63.6			
Sept. 21	64	64	N	Fresh	W.
Sept. 22	72	64	E	do	W.
Sept. 23	75	62	S	do	N.
Sept. 24	58	62	N	Brisk	S.
Sept. 25	60	60	NNE	do	S.
Sept. 26	64	60	SE	Fresh	W.
Sept. 27	72	60	N	Light	E.
Sept. 28	60	58	E	Brisk	W.
Sept. 29	54	58	NW	Fresh	E.
Sept. 30	56	58	E	do	W.
Average	63.5	60.6			

GRAND HAVEN LIGHT, LAKE MICHIGAN.

Date.	Air.	Water.	Direction.	Strength.	Direction of current.
1911.					
June 11	66	62	WSW	Fresh	
June 12	68	61	W	do	
June 13	61	58	NW	Brisk	
June 14	70	50	NE	Light	
June 15	65	52	W	do	
June 16	60	62	SE	do	
June 17	65	61	S	do	
June 18	80	65	NW	do	
June 19	71	61	S	do	
June 20	80	69	NW	do	
Average	68.6	60.1			

Observations of air and water surface temperatures, wind, and current—Continued.

GRAND HAVEN LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1913.					
June 21	76	70	S.	Light	
June 22	77	71	S.	Fresh	
June 23	78	71	S.	do	
June 24	87	70	Calm		
June 25	78	71	SW	Light	
June 26	80	72	S.	do	
June 27	71	70	W.	Fresh	
June 28	76	61	NW	do	
June 29	69	55	W.	Light	
June 30	76	61	SSE	do	
Average	76.8	67.2			
July 1	75	69	S.	Light	NW.
July 2	82	72	SW	do	NE.
July 3	83	76	SW	do	NW.
July 4	84	75	S.	do	N.
July 5	80	78	S.	Fresh	N.
July 6	80	75	NW	Light	SE.
July 7	80	70	SE	Very light	W.
July 8	90	73	S.	Light	N.
July 9	80	75	S.	Fresh	N.
July 10	78	76	SW	Light	NE.
Average	81.2	73.9			
July 11	78	77	SW	Light	N.
July 12	73	71	NW	Fresh	SE.
July 13	71	74	NW	do	S.
July 14	78	72	NW	do	SE.
July 15	75	72	W.	Brisk	SW.
July 16	76	71	NW	Fresh	SE.
July 17	68	65	WNW	do	S.
July 18	75	68	SW	Brisk	NE.
July 19	69	69	NW	Fresh	SE.
July 20	80	70	SW	Light	NE.
Average	74.3	70.9			
July 21	65	71	NW	Fresh	S.
July 22	75	70	NW	Light	SE.
July 23	73	69	S.	High	N.
July 24	75	66	W.	Brisk	E.
July 25	59	65	WNW	Light	S.
July 26	74	67	N.	do	E.
July 27	71	69	S.	Fresh	None.
July 28	75	68	S.	do	N.
July 29	69	68	SW	Light	S.
July 30	78	70	S.	do	N.
July 31	74	73	S.	do	N.
Average	71.6	68.7			
Aug. 1	76	72	S.	Light	N.
Aug. 2	67	71	NW	do	S.
Aug. 3	80	68	NW	do	SE.
Aug. 4	75	68	W.	do	NE.
Aug. 5	84	72	SW	do	NE.
Aug. 6	80	74	W.	do	NW.
Aug. 7	80	70	S.	Fresh	N.
Aug. 8	69	71	NW	do	SE.
Aug. 9	78	71	SW	Light	NE.
Aug. 10	79	71	SE	Fresh	NE.
Average	76.8	70.8			
Aug. 11	70	70	E.	Fresh	W.
Aug. 12	68	66	E.	Light	E.
Aug. 13	74	68	Calm		NW.
Aug. 14	74	71	SW	Light	NE.
Aug. 15	76	67	NW	do	SE.
Aug. 16	74	70	WSW	do	S.
Aug. 17	78	70	W.	do	E.
Aug. 18	69	69	NW	Brisk	S.
Aug. 19	68	56	W.	Light	SE.
Aug. 20	70	53	W.	do	SE.
Average	72.1	66.0			

Observations of air and water surface temperatures, wind, and current—Continued.

GRAND HAVEN LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	68	60	SW	Fresh	NE.
Aug. 22	67	65	NW	Light	E.
Aug. 23	72	56	N	do	S.
Aug. 24	69	49	W	do	W.
Aug. 25	66	51	S	do	N.
Aug. 26	69	54	S	do	None.
Aug. 27	70	60	S	do	N.
Aug. 28	64	52	NNW	Fresh	SW.
Aug. 29	66	48	NW	Light	SE.
Aug. 30	66	46	E	do	W.
Aug. 31	70	48	S	do	N.
Average	67.9	53.5			
Sept. 1	70	50	SW	Light	W.
Sept. 2	65	55	W	Fresh	E.
Sept. 3	67	51	WNW	Light	SW.
Sept. 4	64	52	Calm		E.
Sept. 5	60	55	SSE	Light	NW.
Sept. 6	65	57	N	do	S.
Sept. 7	65	55	SE	do	NE.
Sept. 8	56	60	E	do	W.
Sept. 9	65	55	NW	do	S.
Sept. 10	62	57	S	do	N.
Average	63.9	54.7			
Sept. 11	59	56	S	Light	NW.
Sept. 12	60	58	NW	Fresh	SE.
Sept. 13	62	53	E	do	W.
Sept. 14	50	60	S	do	N.
Sept. 15	62	55	S	Light	NW.
Sept. 16	62	58	SW	do	NE.
Sept. 17	72	58	SE	do	NW.
Sept. 18	66	62	SW	do	NE.
Sept. 19	64	60	NW	Fresh	S.
Sept. 20	64	60	W	Light	NE
Average	62.1	58.0			
Sept. 21	62	58	SE	Light	W.
Sept. 22	62	59	SW	do	NE.
Sept. 23	65	62	S	Fresh	N.
Sept. 24	68	61	SW	do	NE.
Sept. 25	59	61	N	Light	S.
Sept. 26	64	59	NE	do	SW.
Sept. 27	69	63	WNW	do	NE.
Sept. 28	59	56	SE	Fresh	NW.
Sept. 29	55	59	NW	High	SE.
Sept. 30	60	56	SE	Light	NW.
Average	62.3	59.4			

WHITE SHOAL LIGHT, LAKE MICHIGAN.

Date.	Air.	Water.	Direction.	Strength.	Direction of current.
1911.					
June 11	66	52	W	Light	
June 12	56	51	SW	Moderate	
June 13	60	50	NW	Fresh	
June 14	55	53	SW	Light	
June 15	60	56	S	do	
June 16	64	58	Calm		
June 17	64	58	Calm		
June 18	66	58	SW	Light	
June 19	62	59	SW	Fresh	
June 20	64	61	SW	Light	
Average	61.7	55.6			

Observations of air and water surface temperatures, wind, and current—Continued.

WHITE SHOAL LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	68	61	Calm		
June 22	69	61	SW	Moderate	
June 23	56	54	E	Strong	
June 24	57	53	E	do	
June 25	61	55	E	Moderate	
June 26	66	58	E	Light	
June 27	65	58	W	do	
June 28	54	56	NW	Brisk	
June 29	60	56	NE	Light	
June 30	66	57	E	Fresh	
Average	62.2	56.9			
July 1	68	57	SW	Moderate	E.
July 2	66	58	SW	do	W.
July 3	71	61	SW	Light	E.
July 4	72	61	N	do	NW.
July 5	69	61	SW	do	NE.
July 6	65	61	NW	Fresh	SE.
July 7	67	61	E	Moderate	NW.
July 8	75	64	SW	Light	E.
July 9	73	64	WSW	Fresh	E.
July 10	71	65	SSW	Moderate	SE.
Average	69.7	61.3			
July 11	70	65	SW	Strong	NE.
July 12	66	64	SW	Light	S.
July 13	69	64	WSW	Fresh	E.
July 14	68	64	SW	Light	E.
July 15	68	64	SW	do	E.
July 16	68	64	NW	Fresh	SE.
July 17	68	64	SW	Strong	E.
July 18	70	64	S	Light	E.
July 19	68	64	NW	Fresh	E.
July 20	68	64	S	do	NE.
Average	68.3	64.1			
July 21	68	62	NW	Fresh	SE.
July 22	68	64	W	do	E.
July 23	64	63	S	do	NE.
July 24	58	62	W	Gale	
July 25	58	59	NW	Strong	SW.
July 26	64	59	SW	Light	NE.
July 27	66	60	SW	do	NE.
July 28	69	61	SW	Fresh	N.
July 29	64	61	SW	do	SW.
July 30	68	62	SW	Light	NE.
July 31	70	62	S	do	E.
Average	65.2	61.4			
Aug. 1	68	62	SE	Light	NW.
Aug. 2	64	62	SW	Fresh	NE.
Aug. 3	62	62	E	do	SW.
Aug. 4	68	65	E	do	N.
Aug. 5	68	66	SW	do	NE.
Aug. 6	74	68	Calm		SW.
Aug. 7	69	67	E	Strong	W.
Aug. 8	65	65	NW	do	S.
Aug. 9	72	66	W	do	E.
Aug. 10	67	66	NE	Light	NE.
Average	67.7	64.9			
Aug. 11	69	66	NW	Light	S.
Aug. 12	74	67	NNW	do	SW.
Aug. 13	68	66	SW	do	NE.
Aug. 14	67	66	SW	do	NE
Aug. 15	69	66	W	do	S.
Aug. 16	72	68	W	do	E.
Aug. 17	70	63	NW	do	S.
Aug. 18	70	68	NW	Fresh	S.
Aug. 19	72	68	W	do	E.
Aug. 20	68	66	SW	do	NE.
Average	69.9	66.9			

Observations of air and water surface temperatures, wind, and current—Continued.

WHITE SHOAL LIGHT, LAKE MICHIGAN—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	72	68	SW	Fresh	NE.
Aug. 22	62	66	NW	do	S.
Aug. 23	62	66	SW	do	E.
Aug. 24	68	66	SW	Light	NE.
Aug. 25	72	68	SW	do	NE.
Aug. 26	68	68	SW	Fresh	NE.
Aug. 27	70	64	S	Strong	NE.
Aug. 28	63	64	NNW	do	S.
Aug. 29	68	66	NW	Light	SE.
Aug. 30	62	64	N	do	S.
Aug. 31	68	64	SW	Fresh	NW.
Average	66.8	65.8			
Sept. 1	68	64	SW	Light	NE., strong.
Sept. 2	64	64	NW	Gale	SW., strong.
Sept. 3	68	64	NW	Light	S., strong.
Sept. 4	66	64	SW	do	NE., strong.
Sept. 5	64	64	SE	do	NW., strong.
Sept. 6	56	61	NE	do	S., moderate.
Sept. 7	55	60	NE	Strong	SE., mod.
Sept. 8	60	60	NE	Moderate	E., strong.
Sept. 9	60	61	SW	Light	S., moderate.
Sept. 10	63	61	SW	do	S., strong.
Average	62.4	62.3			
Sept. 11	62	61	SW	Strong	E., weak.
Sept. 12	56	59	NW	Moderate	S., moderate.
Sept. 13	65	60	Calm		W., weak.
Sept. 14	60	60	S	Strong	N., weak.
Sept. 15	59	59	SW	do	NE., weak.
Sept. 16	61	59	NW	Light	S., weak.
Sept. 17	60	60	E	Fresh	SW., strong.
Sept. 18	60	64	SW	Light	NE., strong.
Sept. 19	60	64	NW	do	SE., strong.
Sept. 20	59	62	SW	do	NE., strong.
Average	60.2	60.8			
Sept. 21	58	60	E	Light	NW., strong.
Sept. 22	58	60	SW	Fresh	NE., strong.
Sept. 23	58	58	SW	Gale	Do.
Sept. 24	56	58	NW	Strong	Do.
Sept. 25	54	58	N	Light	SW., strong.
Sept. 26	51	58	W	do	Do.
Sept. 27	57	58	NW	Strong	S., moderate.
Sept. 28	47	57	E	Fresh	SW., strong.
Sept. 29	48	55	NE	do	NE., strong.
Sept. 30	52	55	SW	Light	SW., strong.
Average	53.9	57.7			

SPECTACLE REEF, LAKE HURON.

1911.					
June 13	60	48	NW	Fresh	
June 14	50	48	Calm		
June 15	60	50	do		
June 16	60	52	E	Light	
June 17	70	56	Calm		
June 18	68	52	do		
June 19	60	54	NW	Fresh	
June 20	68	56	Calm		
Average	62.0	52.0			

Observations of air and water surface temperatures, wind, and current—Continued.

SPECTACLE REEF, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	64	57	SE	Fresh	
June 22	66	58	NW	do	
June 23	54	56	NE	High	
June 24	52	54	E	do	
June 25	58	55	SE	do	
June 26	62	53	E	Fresh	
June 27	64	54	NW	Light	
June 28	52	55	do	High	
June 29	64	54	SE	Light	
June 30	61	55	do	do	
Average	59.7	55.1			
July 1	70	66	W	Light	
July 2	74	62	Calm		
July 3	78	68	NW	Light	
July 4	70	60	SE	do	
July 5	74	60	NW	do	
July 6	68	60	do	Brisk	
July 7	66	60	SE	Light	
July 8	70	62	do	Fresh	
July 9	80	62	do	Light	
July 10	70	65	NW	do	
Average	72.0	62.5			
July 11	78	65	SW	Brisk	
July 12	64	62	NW	do	
July 13	65	63	do	do	
July 14	73	61	SE	Light	
July 15	75	63	NW	Fresh	
July 16	67	62	do	Light	
July 17	61	62	do	Fresh	
July 18	64	62	SE	Light	
July 19	60	58	NE	do	
July 20	70	62	SE	do	
Average	67.7	62.0			
July 21	64	62	NW	Brisk	
July 22	64	62	do	do	
July 23	61	61	S	Light	
July 24	52	56	SW	Gale	
July 25	50	50	NW	Fresh	
July 26	60	47	Calm		
July 27	62	50	SE	Light	
July 28	58	52	do	do	
July 29	62	51	NW	do	
July 30	72	53	Calm		
July 31	62	52	NE	Fresh	
Average	60.6	54.2			
Aug. 1	66	64	SE	Light	
Aug. 2	58	56	NW	do	
Aug. 3	66	64	Calm		
Aug. 4	66	58	SE	Light	
Aug. 5	68	60	SE	do	
Aug. 6	70	62	Calm		
Aug. 7	68	58	SE	High	
Aug. 8	60	58	NW	Brisk	
Aug. 9	66	58	NW	Fresh	
Aug. 10	70	59	Calm		
Average	65.8	59.7			
Aug. 11	66	58	NW	Light	
Aug. 12	70	60	NW	do	
Aug. 13	70	60	Calm		
Aug. 14	68	62	NW	Light	
Aug. 15	66	64	NW	Fresh	
Aug. 16	68	66	NW	Light	
Aug. 17	66	64	NW	Brisk	
Aug. 18	64	64	NW	do	
Aug. 19	62	62	NW	Light	
Aug. 20	68	64	SW	do	
Average	66.8	62.4			

Observations of air and water surface temperatures, wind, and current—Continued.

SPECTACLE REEF, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	70	62	SW	Light	
Aug. 22	62	62	NW	Brisk	
Aug. 23	66	60	NW	Fresh	
Aug. 24	70	61	SW	Light	
Aug. 25	73	63	Calm		
Aug. 26	71	64	SE	Fresh	
Aug. 27	76	64	S	Light	
Aug. 28	61	62	NW	High	
Aug. 29	53	60	N	Light	
Aug. 30	58	61	SE	Fresh	
Aug. 31	62	60	SE	do	
Average	65.6	61.7			
Sept. 1	64	62	Calm		
Sept. 2	62	62	NW	Brisk	
Sept. 3	62	60	W	Light	
Sept. 4	64	60	SE	do	
Sept. 5	60	60	NE	Brisk	
Sept. 6	58	60	NE	do	
Sept. 7	52	58	SE	Gale	
Sept. 8	56	56	SE	Light	
Sept. 9	68	60	SW	do	
Sept. 10	61	59	NW	do	
Average	60.7	59.7			
Sept. 11	64	58	SW	Fresh	
Sept. 12	47	56	NW	High	
Sept. 13	56	57	E	Light	
Sept. 14	56	56	SE	Fresh	
Sept. 15	64	57	SW	High	
Sept. 16	60	58	NW	Light	
Sept. 17	60	56	SE	do	
Sept. 18	62	58	SE	do	
Sept. 19	58	56	NW	Brisk	
Sept. 20	62	58	Calm		
Average	58.9	57.0			
Sept. 21	62	57	SE	Light	
Sept. 22	65	58	SE	do	
Sept. 23	65	59	SE	Fresh	
Sept. 24	53	57	NE	do	
Sept. 25	52	57	NE	do	
Sept. 26	60	57	Calm		
Sept. 27	59	57	SW	High	
Sept. 28	52	56	E	Light	
Sept. 29	48	54	SE	High	
Sept. 30	58	54	W	Light	
Average	57.4	56.6			

POE REEF LIGHT VESSEL, LAKE HURON.

Date.	Air.	Water.	Direction.	Strength.	Direction of current.
1911.					
June 11	56	53	NE	Light	SW.
June 12	60	52	SE	do	W.
June 13	64	50	NW	Fresh	E.
June 14	64	54	NW	Light	W.
June 15	69	56	NW	do	N.
June 16	65	56	SE	do	W.
June 17	70	55	E	do	NW.
June 18	67	56	NW	do	SE.
June 19	69	60	NW	do	S.
June 20	71	64	E	do	W.
Average	65.5	55.6			

Observations of air and water surface temperatures, wind, and current—Continued.

POE REEF LIGHT VESSEL, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	70	64	E	Light	W.
June 22	73	65	W	do	E.
June 23	52	55	E	Strong	W.
June 24	55	49	E	do	W.
June 25	60	56	SE	Light	SW.
June 26	59	59	E	Fresh	SE.
June 27	67	57	NW	Light	SE.
June 28	54	52	NW	do	SE.
June 29	60	55	E	do	W.
June 30	64	54	NE	Fresh	SE.
Average	61.4	56.6			
July 1	72	62	NE	Light	E.
July 2	79	62	W	do	E.
July 3	74	62	W	do	W.
July 4	74	64	E	do	W.
July 5	77	64	NW	do	E.
July 6	72	64	NW	Fresh	E.
July 7	70	62	E	do	W.
July 8	74	62	SE	Light	E.
July 9	90	66	SW	Fresh	E.
July 10	75	66	NW	Light	SE.
Average	75.7	63.4			
July 11	80	66	NW	Strong	E.
July 12	67	63	NW	Moderate	SE.
July 13	71	63	N	Light	NW.
July 14	72	65	W	do	E.
July 15	75	65	SW	do	NE.
July 16	66	65	NW	do	SE.
July 17	69	65	NW	do	SE.
July 18	69	64	E	do	W.
July 19	66	64	NW	Fresh	SE.
July 20	71	66	NE	Light	SW.
Average	70.6	64.6			
July 21	69	64	NW	Fresh	SW.
July 22	70	64	W	Light	E.
July 23	63	62	S	do	N.
July 24	59	56	W	Fresh	E.
July 25	58	57	NW	do	SE.
July 26	64	58	E	Light	W.
July 27	68	59	E	do	S.
July 28	70	58	S	do	E.
July 29	70	61	Calm		SE.
July 30	72	63	E	Light	SE.
July 31	68	64	N	do	SE.
Average	66.4	60.5			
Aug. 1	80	64	S	Light	N.
Aug. 2	75	63	W	do	E.
Aug. 3	68	59	NE	do	W.
Aug. 4	70	60	E	do	W.
Aug. 5	70	66	NE	do	SE.
Aug. 6	75	65	NE	do	SW.
Aug. 7	69	62	E	Fresh	W.
Aug. 8	64	56	W	do	E.
Aug. 9	72	62	NW	do	SE.
Aug. 10	64	60	NE	Light	W.
Average	70.7	61.7			
Aug. 11	69	61	NE	Light	E.
Aug. 12	68	63	NW	do	SW.
Aug. 13	69	63	E	do	E.
Aug. 14	70	65	N	do	SE.
Aug. 15	76	64	NW	do	SE.
Aug. 16	78	69	Calm		SW
Aug. 17	69	66	NW	Light	SE
Aug. 18	68	65	NW	Fresh	S.
Aug. 19	66	64	NW	Light	SE
Aug. 20	76	66	NW	do	S.
Average	70.9	64.6			

Observations of air and water surface temperatures, wind, and current—Continued.

POE REEF LIGHT VESSEL, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Aug. 21	72	64	SW	Fresh	NE.
Aug. 22	65	64	NW	do	SE.
Aug. 23	68	64	NW	Light	SE.
Aug. 24	69	65	N	do	None.
Aug. 25	69	65	E	do	SE.
Aug. 26	73	66	NW	do	SE.
Aug. 27	75	64	SW	Fresh	E.
Aug. 28	65	59	W	do	E.
Aug. 29	62	58	N	Light	SW.
Aug. 30	62	61	E	Fresh	W.
Aug. 31	65	66	E	Light	N.
Average	67.7	63.3			
Sept. 1	68	64	E	Light	E.
Sept. 2	66	58	NW	Fresh	E.
Sept. 3	65	58	NW	Light	E.
Sept. 4	64	59	E	do	W.
Sept. 5	66	57	E	do	W.
Sept. 6	64	58	NE	do	SW.
Sept. 7	59	54	E	Fresh	W.
Sept. 8	56	55	SE	do	E.
Sept. 9	59	55	NW	Light	E.
Sept. 10	65	57	W	do	SE.
Average	63.2	57.5			
Sept. 11	66	57	SW	Light	E.
Sept. 12	55	56	NW	do	SE.
Sept. 13	58	57	E	do	W.
Sept. 14	57	56	S	Fresh	W.
Sept. 15	67	58	W	do	E.
Sept. 16	63	58	SW	Light	E.
Sept. 17	60	56	E	Fresh	W.
Sept. 18	66	55	S	Light	E.
Sept. 19	64	56	NW	do	E.
Sept. 20	60	57	N	do	SW.
Average	61.6	56.6			
Sept. 21	60	56	SE	Light	NW.
Sept. 22	66	57	SW	do	E.
Sept. 23	67	58	SW	do	NE.
Sept. 24	59	56	NE	Fresh	SW.
Sept. 25	52	55	N	Light	SE.
Sept. 26	57	57	NE	do	SW.
Sept. 27	62	57	W	Strong	E.
Sept. 28	59	55	E	Light	W.
Sept. 29	55	52	NE	Fresh	W.
Sept. 30	54	54	SW	Light	E.
Average	59.1	55.7			

HARBOR BEACH LIGHT, LAKE HURON.

1911.					
June 11	62	56	SE	Fresh	
June 12	65	60	SW	do	
June 13	64	55	N	do	
June 14	64	52	N	Light	
June 15	62	62	N	do	
June 16	62	60	S	do	
June 17	64	62	SE	do	
June 18	64	66			
June 19	74	70	SE	Light	
June 20	68	65	N	do	
Average	65.9	60.8			

Observations of air and water surface temperatures, wind, and current—Continued.

HARBOR BEACH LIGHT, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
June 21	68	65	E	Light	
June 22	84	77	W	Fresh	
June 23	64	62	NE	do	
June 24	68	64	NE	Light	
June 25	78	70	SE	do	
June 26	82	74	SE	do	
June 27	82	60	SW	Fresh	
June 28	68	52	NE	do	
June 29	62	65	NE	Moderate	
June 30	76	62	SE	Light	
Average	73.2	65.1			
July 1	93	67	W	Light	
July 2	98	67	W	do	
July 3	96	71	W	do	
July 4	74	68	N	do	
July 5	86	72	E	do	
July 6	76	68	N	Fresh	
July 7	78	68	NE	do	
July 8	68	66	SE	Light	
July 9	94	70	SW	do	
July 10	86	72	Calm		
Average	84.9	68.9			
July 11	86	64	SW	Light	
July 12	72	67	SE	do	
July 13	72	68	NE	do	
July 14	78	70	NE	do	
July 15	80	60	SW	Fresh	
July 16	72	65	E	Light	
July 17	65	64	N	Fresh	
July 18	76	67	SW	do	
July 19	80	68	SW	do	
July 20	70	64	SE	do	
Average	75.1	65.7			
July 21	66	68	NE	Fresh	
July 22	70	65	NW	do	
July 23	78	66	SE	do	
July 24	65	60	W	Light	
July 25	68	56	NW	Fresh	
July 26	68	60	E	Light	
July 27	70	66	SE	do	
July 28	70	63	SE	do	
July 29	66	62	W		
July 30	72	68	SE		
July 31	70	66	SE		
Average	69.4	63.6			
Sept. 1	80	66	S	Light	
Sept. 2	78	68	SW	do	
Sept. 3	66	66	W	do	
Sept. 4	69	64	SE	Fresh	
Sept. 5	68	64	SE	do	
Sept. 6	62	64	NE	do	
Sept. 7	60	60	NE	do	
Sept. 8	72	62	E	Light	
Sept. 9	64	62	NE	do	
Sept. 10	78	68	W	do	
Average	69.7	64.4			
Sept. 11	78	68	SW	Fresh	
Sept. 12	60	56	NW	do	
Sept. 13	54	56	NE	Light	
Sept. 14	62	60	SE	Fresh	
Sept. 15	72	64	W	do	
Sept. 16	76	63	W	do	
Sept. 17	65	64	NE	Light	
Sept. 18	70	65	S	Fresh	
Sept. 19	62	62	N	do	
Sept. 20	59	58	NE	Light	
Average	65.8	61.6			

Observations of air and water surface temperatures, wind, and current—Continued.

HARBOR BEACH LIGHT, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
Sept. 21	60	62	SE	Fresh	
Sept. 22	64	62	SE	Light	
Sept. 23	65	63	SE	Fresh	
Sept. 24	70	65	NE	Light	
Sept. 25	64	60	NE	do	
Sept. 26	58	56	N	do	
Sept. 27	62	68	NW	Fresh	
Sept. 28	54	56	E	do	
Sept. 29	56	58	W	do	
Sept. 30	58	56	NE	Light	
Average	61.1	60.6			

LIGHTSHIP NO. 61, OFF FORT GRATIOT, LAKE HURON.

Date.	Air.	Water.	Direction.	Strength.	Direction of current.
1911.					
June 11	78	59	SW	Light	
June 12	60	57	WSW	Fresh	
June 13	62	58	NW	Moderate	
June 14	65	58	NE	Light	
June 15	64	57	NE	do	
June 16	68	58	NE	do	
June 17	64	58	SE	do	
June 18	72	59	SE	do	
June 19	78	60	Calm		
June 20	79	60	NE	Moderate	
Average	69.0	58.4			
June 21	81	62	NE	Moderate	
June 22	82	63	WNW	Brisk	
June 23	86	64	NE	Light	
June 24	80	64	SE	do	
June 25	72	65	SSE	do	
June 26	82	65	SE	do	
June 27	84	66	W	Fresh	
June 28	67	66	NE	Moderate	
June 29	72	67	NE	do	
June 30	70	67	NE	do	
Average	77.6	64.9			
July 1	84	69	Calm		
July 2	86	69	W	Light	
July 3	84	70	WNW	Moderate	
July 4	78	70	NE	do	
July 5	80	71	SW	do	
July 6	78	70	NE	do	
July 7	80	70	NE	do	
July 8	80	71	NE	do	
July 9	86	72	S	do	
July 10	85	72	N	Light	
Average	82.1	70.4			
July 11	82	72	W	Moderate	
July 12	78	71	NE	Light	
July 13	72	70	NW	do	
July 14	82	71	WSW	Moderate	
July 15	72	71	SW	do	
July 16	70	70	SSW		
July 17	69	70	NW	Fresh	
July 18	78	69	SW	Moderate	
July 19	76	68	SW	Fresh	
July 20	86	69	NE	Light	
Average	76.5	70.1			

Observations of air and water surface temperatures, wind, and current—Continued.

LIGHTSHIP NO. 61, OFF FORT GRATIOT, LAKE HURON—Continued.

Date.	Temperature.		Wind.		Direction of current.
	Air.	Water.	Direction.	Strength.	
1911.					
July 21	70	68	NE	Fresh	
July 22	80	68	NW	do	
July 23	74	67	WSW	Moderate	
July 24	70	66	W	Gale	
July 25	60	65	N	Brisk	
July 26	72	64	SW	Light	
July 27	68	64	ENE	do	
July 28	78	65	S	do	
July 29	76	66	SW	Moderate	
July 30	78	66	SW	do	
July 31	80	67	SW	do	
Average	73.2	66.0			
Aug. 1	80	66	SW	Gale	
Aug. 2	80	68	SW	Light	
Aug. 3	70	67	N	do	
Aug. 4	82	68	E	do	
Aug. 5	84	69	SE	do	
Aug. 6	85	69	NNW	do	
Aug. 7	84	70	SE	do	
Aug. 8	80	69	NW	Moderate	
Aug. 9	84	69	E	Light	
Aug. 10	84	70	NE	do	
Average	81.3	68.5			
Aug. 11	70	68	N	Light	
Aug. 12	72	67	S	do	
Aug. 13	78	67	E	do	
Aug. 14	78	68	E	do	
Aug. 15	76	68	N	do	
Aug. 16	80	68	S	do	
Aug. 17	78	69	E	do	
Aug. 18	72	68	N	Fresh	
Aug. 19	68	67	NE	do	
Aug. 20	68	66	NE	Moderate	
Average	74.0	67.6			
Aug. 21	77	68	S	Light	
Aug. 22	82	68	SW	Fresh	
Aug. 23	76	67	NE	Moderate	
Aug. 24	77	67	E	Light	
Aug. 25	74	66	NE	do	
Aug. 26	86	68	NE	do	
Aug. 27	80	68	N	Fresh	
Aug. 28	78	67	N	do	
Aug. 29	74	66	NNE	Brisk	
Aug. 30	76	65	NE	Fresh	
Aug. 31	72	65	NE	Moderate	
Average	77.5	66.8			
Sept. 1	76	67	NE	Light	
Sept. 2	80	67	SW	do	
Sept. 3	69	66	NE	Fresh	
Sept. 4	70	66	NE	Light	
Sept. 5	72	67	NE	do	
Sept. 6	64	66	ESE	Fresh	
Sept. 7	68	65	NE	do	
Sept. 8	69	65	NE	Light	
Sept. 9	78	65	NW	do	
Sept. 10	74	65	NW	do	
Average	72.0	65.9			
Sept. 11	76	65	E	Light	
Sept. 12	62	64	N	Brisk	
Sept. 13	68	64	NE	Moderate	
Sept. 14	65	62	SE	Fresh	
Sept. 15	78	64	NW	Light	
Average	69.8	63.8			

Observations of air and water surface temperatures, wind, and current—Continued.

SAULT STE. MARIE AND SAILORS ENCAMPMENT, MICH., ST. MARYS RIVER.

Date.	Temperature of water.		Direction and strength of wind.	
	Sault Ste. Marie.	Sailors Encampment.	Sault Ste. Marie.	Sailors Encampment.
1911.				
June 12	49.1	53.0	SE., light	S., light.
June 13	49.1	52.0	NW., fresh	NW., fresh.
June 14	49.1	52.5	NW., light	W., fresh.
June 15	48.7	52.0	NW., fresh	NW., fresh.
June 16	50.0	52.0	Calm	SE., fresh.
June 17	50.0	52.0	NW., light	Do.
June 18				
June 19	53.6	53.0	NW., fresh	SE., light.
June 20	54.5	53.0	do	NW., fresh.
Average	50.5	52.4		
June 21	54.9	54.0	Calm	SE., light.
June 22	54.5	55.0	do	Do.
June 23	54.5	56.0	E., light	E., fresh.
June 24	54.9	56.0	SE., light	SE., fresh.
June 25				
June 26	54.0	56.0	SE., light	S., light.
June 27	51.4	58.0	W., fresh	NW., fresh.
June 28	49.6	56.0	NW., fresh	W., fresh.
June 29	50.0	56.0	SE., light	SW., fresh.
June 30	50.9	55.0	do	
Average	52.7	55.7		
July 1	52.7	56.0	Calm	SE., light.
July 2				
July 3	56.3	56.0	W., light	Do.
July 4				
July 5	56.3	60.0	Calm	Do.
July 6	57.2	61.0	NW., fresh	Do.
July 7	59.0	65.0	SE., light	SE., fresh.
July 8	59.0	63.0	SE., fresh	Do.
July 9				
July 10	59.9	64.0	W., light	Do.
Average	57.2	60.7		
July 11	59.9	64.0	SW., fresh	SE., gale.
July 12	60.8	64.0	NW., fresh	SE., fresh.
July 13	59.9	64.0	NW., light	Do.
July 14	59.9	63.0	W., light	Do.
July 15	60.8	62.0	SW., fresh	Do.
July 16				
July 17	60.8	62.0	W., light	SE., light.
July 18	62.6	62.0	SE., light	SE., fresh.
July 19	62.6	62.0	NW., fresh	NW., fresh.
July 20	62.6	62.0	Calm	SE., fresh.
Average	61.1	62.7		
July 21	60.8	64.0	NW., fresh	NW., fresh.
July 22	60.8	63.0	do	W., fresh.
July 23				
July 24	59.0	60.0	Calm	SE., fresh.
July 25	59.0	60.0	NW., fresh	W., fresh.
July 26	59.0	61.0	W., light	Do.
July 27	59.0	61.0	NW., light	E., fresh.
July 28	59.9		SE., light	
July 29	62.6	61.0	Calm	SW., fresh.
July 30				
July 31	62.6	60.0	SE., light	S., fresh.
Average	60.3	61.2		
Aug. 1	60.8	63.0	SE., light	W., fresh.
Aug. 2	60.8	63.0	SW., light	Do.
Aug. 3	60.8	63.0	E., light	W., light.
Aug. 4	62.6	68.0	SE., light	E., light.
Aug. 5	62.6	67.0	S., light	E., fresh.
Aug. 6				
Aug. 7	61.7	67.0	SE., fresh	Do.
Aug. 8	60.8	63.0	W., fresh	W., fresh.
Aug. 9	59.0	67.0	NW., fresh	Do.
Aug. 10	59.0	67.0	W., light	SW., light.
Average	60.9	65.3		

Observations of air and water surface temperatures, wind, and current—Continued.

SAULT STE. MARIE AND SAILORS ENCAMPMENT, MICH., ST. MARYS RIVER—Contd

Date.	Temperature of water.		Direction and strength of wind.	
	Sault Ste. Marie.	Sailors Encampment.	Sault Ste. Marie.	Sailors Encampment.
1911.				
Aug. 11	59.0	62.0	NW., light	NW., fresh.
Aug. 12	59.0	68.0	W., light	S., fresh.
Aug. 13				
Aug. 14	59.0	65.0	Calm	NW., light.
Aug. 15	59.0	63.0	NW., fresh	W., light.
Aug. 16	60.0	66.0	W., light	W., fresh.
Aug. 17	60.0	64.0	NW., fresh	NW., fresh.
Aug. 18	62.0	64.0	do	Do.
Aug. 19	61.0	67.0	NW., light	SE., fresh.
Aug. 20				
Average	59.9	64.9		
Aug. 21	62.0		SW., fresh	
Aug. 22	61.0		NW., fresh	
Aug. 23	61.0		NW., light	
Aug. 24	61.0		Calm	
Aug. 25	62.0		do	
Aug. 26	62.0		SW., light	
Aug. 27				
Aug. 28	61.0	63.0	NW., fresh	W., fresh.
Aug. 29	60.0		do	
Aug. 30	60.0	61.0	SE., light	
Aug. 31	60.0	60.0	do	
Average	61.0	61.3		
Sept. 1	59.0	60.0	Calm	SE., light.
Sept. 2	60.0	60.0	NW., brisk	
Sept. 3				
Sept. 4				
Sept. 5	60.0	60.0	SE., light	
Sept. 6	60.0	60.0	Calm	
Sept. 7	58.0	59.5	E., light	W., light.
Sept. 8	58.0	59.5	Calm	Do.
Sept. 9	58.0	60.0	W., light	Do.
Sept. 10				
Average	59.0	59.9		
Sept. 11	58.0	61.0	SW., light	SE., light.
Sept. 12	58.0	59.0	NW., fresh	NW., brisk.
Sept. 13	58.0	58.0	Calm	SE., light.
Sept. 14	58.0	58.0	SE., light	SE., fresh.
Sept. 15	58.0	58.5	W., fresh	SW., fresh.
Sept. 16	58.0	59.0	NW., light	NW., light.
Sept. 17				
Sept. 18	58.0	61.0	Calm	SE., light.
Sept. 19	57.0	60.0	NW., fresh	NW., light.
Sept. 20	57.0	59.0	W., light	Do.
Average	57.8	59.3		
Sept. 21	57.0	58.5	SE., light	Calm.
Sept. 22	57.0	58.5	SW., light	SE., light.
Sept. 23	58.0	59.0	S., light	Do.
Sept. 24				
Sept. 25	57.0	57.5	NW., light	NW., light.
Sept. 26	57.0	57.0	W., light	SE., light.
Sept. 27	56.0	57.0	NW., brisk	NW., fresh.
Sept. 28	55.0	55.0	Calm	Calm.
Sept. 29	54.0	54.0	do	NE., light.
Sept. 30	54.0	54.0	W., light	Calm.
Average	56.1	56.7		

Observations of air and water surface temperatures, wind, and current—Continued.

MACKINAC ISLAND, MICH.

Date.	Temperature.		Wind.		Direction of current.[1]
	Air.	Water.	Direction.	Strength.	
1911.					
June 11	57	51	S. by W.	Light	E., strong.
June 12	58	52	W. by S.	do	W., 1.25.
June 13	65	50	N	do	
June 14	62	50	do	do	E., 1.
June 15	59	54	SW	do	E.
June 16	60	55	do	do	
June 17	62	58	SE	do	E., 1.2.
June 18	68	58	N. by W	do	E., fast.
June 19			W	Moderate	Do.
June 20	72	60	E	Light	E., slow.
Average	62.6	54.2			
June 21	73	60			W., 0.3.
June 22	72	60	SW	Light	E., 0.8.
June 23	57	58	E	Heavy	W., fast.
June 24	56	58	do	Light	E., fast.
June 25	58	59	do	Moderate	W., 1.
June 26	61	55	NW	Light	E., slow.
June 27	67	59	W	do	E., 0.7.
June 28 (7 a. m.)	58	58	NW	Moderate	E., 0.5.
June 28 (3 p. m.)	58	58	do	do	W., 1.4.
June 29	58	59	E	do	W., 0.4.
June 30 (8 a. m.)	67	55	do	Light	Do.
June 30 (10 a. m.)	67	55	N	Moderate	E., 0.4.
June 30 (12 m.)			E	do	W., 0.4.
Average	62.7	57.8			
July 1	82	62	W	Moderate	
July 2	77	60	do	Light	E., slow.
July 3	75	59	do	do	E., very slow
July 4	72	60	E	do	W., 1.1.
July 5	72	60	NW	do	E., 0.6.
July 6	71	60	W	do	
July 7	66	60	E	do	W., slow.
July 8	67	61	NE	do	E., slow.
July 9	84	64	W	do	E., 0.5.
July 10	72	64	do	do	Do.
Average	73.8	61.0			
July 11	74	64	SW	Light	E., fast.
July 12	62	59	do	do	E., slow.
July 13	64	61	do	do	E.
July 14	70	62	W	do	E., 0.9.
July 15	74	60	do	do	E., 1.5.
July 16	62	61	NE	do	W., 3.
July 17	68	62	SW	do	E., 1.
July 18	70	62	S	do	W., fast.
July 19	64	62	NE	do	E., 1.8.
July 20	72	62	NW	do	E., 0.2.
Average	68.0	61.5			
July 21	72	60	W	Light	E., fast.
July 22	68	60	do	do	E., 0.5.
Average	70.0	60.0			

[1] Figures refer to miles per hour.

APPENDIX D.

Gen. WILLIAM H. BIXBY,
President of Board.

SIR: In compliance with the request of the board I have prepared the following considerations in connection with that clause of the act of Congress creating the board, which directs that the board shall consider and report upon the improvement of the Mississippi River, between the mouth of the Illinois River and the mouth of the Ohio River, by the construction of a dam at or near Jefferson Barracks and a dam at or near Commerce and the development of water power incidentally created by such dams.

The Lakes to the Gulf Deep Waterway Association, at a hearing at St. Louis, presented orally to this board by the consulting engineer of that association, Mr. Lyman E. Cooley, civil engineer, the general features of this proposed improvement of the Mississippi River and the incidental development of water power, together with details as to various related points. At the same time Mr. Cooley gave to the board a written statement including a memorandum as to the middle Mississippi, Grafton to Cairo, with a supplemental memorandum as to water power with steam auxiliary. Soon afterwards he sent to the president of the board a memorandum (No. 2) covering "certain specific questions asked at the hearing" and being "an extension of the memorandum furnished at the hearing." He also sent a copy of a profile referred to in these memoranda.

These documents are appended hereto as Appendix No. 1.

There is given in them in considerable detail an exposition of the project thus suggested as an improvement of the river between Grafton, the mouth of the Illinois, and Cairo, the mouth of the Ohio. In these documents it is stated that the distance between these points is 212 miles, with a fall at normal low water of 132 feet and an average slope of 0.622 foot per mile; that the significant high water is the bank-full stage above which the water has ranged only 80 days in 40 years, that extreme high water as in 1844 and 1903 occurs perhaps twice in a century, but must be reckoned with in constructing embankments and provision made for these volumes at structures; the bank-full volume is taken at 620,000 second-feet (606,000 plus 14,000 from Lake Michigan); the significant low water is taken as at 1 foot on St. Louis gauge with a volume of 41,000 second-feet below which the water has ranged for 48 days in 40 years, this volume to be increased to 55,000 second-feet by the addition from Lake Michigan; the project proposed involves the construction of two dams which together with changes in the river bed below will, it is stated, greatly reduce the declivity and enable a larger depth to be obtained for navigation; that a free fall at each dam will be produced between the significant stages hereinbefore stated and a large water power made incidentally available; one of the dams to be located from 7 to 12 miles below the Eads Bridge at St. Louis, the other in the vicinity of Commerce, some 36 miles above the confluence of the Ohio River; for each dam a spillway length is proposed of 4,000 feet, of which 3,000 is to be fixed weir and 1,000 to consist of bear-trap section with a range of 15 to 16 feet below fixed weir level; the fixed spillway to be an equilateral slant form upstream, the apex inclosing 60 degrees, the bear-trap section athwart the stream, thus giving a net length athwart the stream of 2,500 feet, or with abutments one-half mile; the arrangement of bear trap and spillways can be varied to suit conditions.

The suggested elevation of the crest of the dam near Jefferson Barracks is 413 Memphis datum.

The location suggested for the other proposed dam is at or near Commerce with an elevation of crest of 343.

The above are extracts from the documents presented as above explained and appended hereto.

Jefferson Barracks lie on the west or Missouri bank of the Mississippi River south of the city of St. Louis and about 11 miles below the Eads Bridge. At the request of this board a survey was made by the United States Engineer Office at St. Louis, and an outline map, profile, and cross section of the river were furnished, extending from the Eads Bridge to Waters Point, below the mouth of the Meramec River, a distance of 21 miles. This showed the locations and depths of some 60 borings to bedrock, six sections of the river channel, and two cross sections extending from Missouri bank to the bluffs on the Illinois or eastern bank. The profile shows the plane of gauge zeros, the slopes of standard low water, and of the floods of 1903 and of 1844. It also indicates an approximate profile of the elevation of bedrock along a line about 3,000 feet from the Missouri bluffs, thus showing the depths which the foundations of a dam must reach.

The elevation of the bedrock was, at the two deeper piers of the Eads Bridge, 293.8 and 301.8 (all elevations are referred to Memphis datum); at the two deeper piers of the new municipal bridge (a little over a mile below Eads Bridge), 292 and 302. The bedrock rises thence till at a point opposite the southern part of St. Louis, about 7¼ miles below Eads Bridge, it is at about 308. This is at the foot of Steins Street. Thence the rock falls to a point 17 miles from Eads Bridge, where it is 263. Then it rises to a point near the mouth of the Meramec River, where it is 303.7. Thence it drops southerly.

The location opposite Steins Street has the highest bedrock, and a full cross section with borings to rock was there made, extending from the Missouri rocky bank to the high Illinois bluff. A description of this cross section follows later.

Another full cross section with borings to rock, at 13 miles below Eads Bridge, is given on the chart made in 1908, accompanying the report of the Board on Survey of the Mississippi (the 14-foot channel report). At this location the bedrock under the channel is at elevation 290.6. The low-water channel has a width of 3,200 feet; at bank-full stage, a width of 3,300 feet. At the plane of the flood of 1903 the water would extend to the Illinois bluff with a width of 17,300 feet. Greatest depth of river channel below extreme low water, 13 feet. Bedrock is about 94 feet below extreme low water.

Another full cross section with borings to rock was made 18½ miles below Eads Bridge, near the mouth of the Meramec River. At this location the width of the river channel at low water is 3,000 feet, and 3,300 feet when the river is 21 feet above the plane of zero stage. At bank-full stage the width is 4,200 feet. There is a levee here which apparently guards the lowlands up to the elevation of the flood of 1903. The land between this levee and the Illinois bluff is from 2 to 12 feet below the plane of that flood, and any increase of flood elevation above the plane of 1903 would take the water to that bluff, with a total width of 22,900 feet (4⅓ miles). This would be the width of area submerged by a flood of a volume such as that of 1844. The greatest depth from low water to river bottom in existing channel at this particular point is 9 feet. The bedrock here under the river channel at 2,500 feet from the Missouri bank is about 93 feet below low water, and this depth continues to 3,000 feet from that bank. The bedrock then rises slightly, and at 6,000 feet is about 87 feet below the plane of low water.

At the Stein Street location the width of the channel at low water (plane of zero, St. Louis gauge) is about 1,660 feet. At bank-full stage 1,900 feet. At a slight rise—about 2 feet—above bank-full stage, the water will overflow the bank and the low ground to the east and extend to an existing levee at a distance of 4,665 feet from the Missouri bank. This levee is at the elevation of the plane of the flood of 1903 and is designed to protect the village of East Carondelet. A slight elevation of a flood above the plane of 1903 would carry the water to the Illinois bluffs and give a width of water of 19,580 feet (3.7 miles). The land between this levee and the Illinois bluff is fairly level at an elevation from 4 to 12 feet below the plane of flood of 1903. The elevation of the flood of 1844 was at this point 424.6 and of that of 1903, 420.6. The greatest depth from low water to river bottom in existing channel at this point is 17 feet. Bedrock under the river channel is 76 feet below low water at 1,700 feet from the Missouri bluff and 77½ feet below low water at 3,000 feet and 76 feet at 6,000 feet.

Plate No. 1 is a section of the valley at Stein Street from the Missouri to the Illinois bluff. Plate No. 2 is a section on larger scale of the river and adjacent territory showing elevations of rock and of earth on the line of the proposed dam.

The depth of bedrock below low water is an important element in a study of the possibility of construction and in an estimate of cost of a dam. This depth at the three characteristic sections is:

	Feet
At 7¼ miles below Eads Bridge	77½
At 13 miles below Eads Bridge	94
At 18½ miles below Eads Bridge	93

In this respect the location at Stein Street, 7¼ miles below Eads Bridge, is the best.

The construction of a dam at or near Jefferson Barracks will, to a greater or less extent, affect the elevations of the river surface in front of and above the cities of St. Louis and East St. Louis. In a report, May 3, 1906 (H. Doc. No. 772, 59th Cong., 1st sess.), made by Maj. Thomas L. Casey, Corps of Engineers, upon the harbor and approaches to St. Louis, with a view to preventing floods by reason of obstructions in the Mississippi River, and in the appendix to that report, and in the report of the division engineer, the report of the Board of Engineers for Rivers and Harbors, and the letter of transmission of the Chief of Engineers, all of which are printed in the document, much information is given and conclusions expressed bearing directly upon the questions now under consideration. Summarized, some of these are as follows:

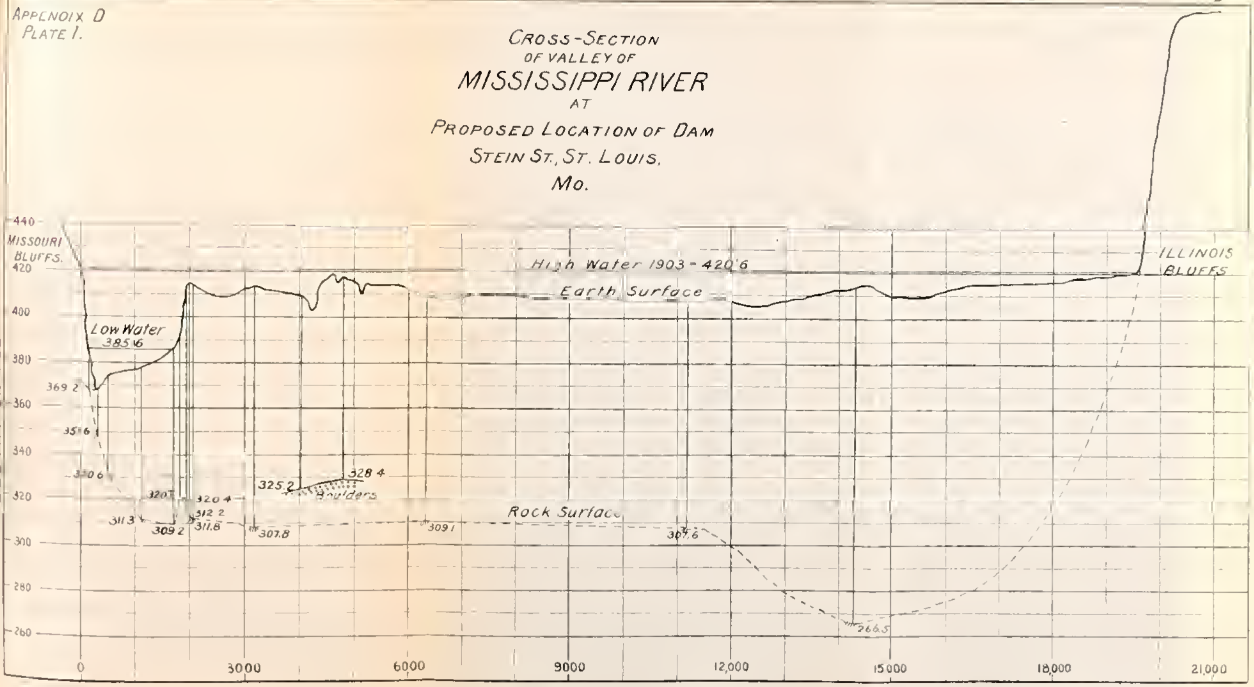
The heights of floods along the harbor front of St. Louis have of late years increasingly overtopped the banks by reason of the obstruc-

War Department

Corps of Engineers, U.S Army.

Appendix D
Plate I.

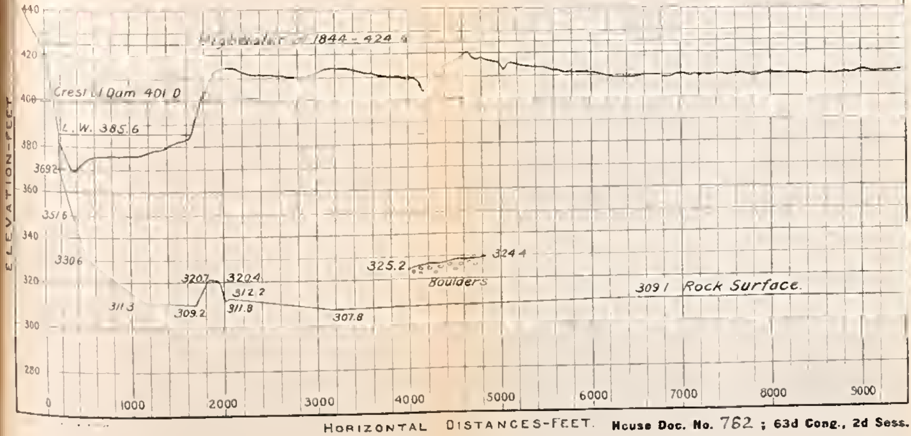
CROSS-SECTION OF VALLEY OF MISSISSIPPI RIVER AT PROPOSED LOCATION OF DAM STEIN ST., ST. LOUIS, MO.



House Doc. No. 762; 63d Cong., 2d Sess.

APPENDIX D
PLATE 2.

CROSS-SECTION
OF
MISSISSIPPI RIVER
AT
PROPOSED LOCATION OF DAM
STEIN ST, ST. LOUIS,
MO



tion and narrowing of the Mississippi River by bridges, with their piers and approaches, by railway inclines and embankments, loading tipples, elevators, warehouses, power houses, local levees, etc., built along the water front on both sides of the river. The large district in Illinois on the east side of the river, known as the American Bottoms, is from 2 to 10 miles wide and embraces about 160 square miles, most of which is subject to overflow, being barely above the plane of the ordinary yearly high water. It is fertile, valuable, and the seat of many rapidly growing manufacturing towns, including East St. Louis, Brooklyn, Venice, Madison, and Granite City; is crossed by 16 trunk railway lines, 6 electric roads, and is a vast railroad yard and terminus. Its population (1905) was 50,000, increasing rapidly. The greater part of the district had been made reasonably secure by levees against flood as in 1892, rising as high as 6 feet above bankfull stage; but with the crowding of many interests along the main river bank, gradually narrowing the stream to a low-water width of 1,600 feet and a high-water width of less than 2,500 feet, and the consequent raising of the flood levels, these structures were found inadequate in the flood of 1903 and a comprehensive scheme for protection was urgently demanded. An examination was made of the records of previous floods and of the effect of contractions of the river. The greatest flood recorded was that of 1844, which reached 41.4 on the St. Louis gauge. Others were in 1785, 40.7; 1851, 36.6; 1858, 37; 1892, 36; 1903, 38, the last causing more pecuniary damage locally than all the others combined owing to the increased population and greater interests involved. But this flood of 1903, the third highest at St. Louis, was there abnormally high, rising about 2.7 feet above the natural height due to its volume, as evidenced by comparison of its high-water marks with those of 1844 at places below the city where the cross-sections have not been materially changed. In the order of volumes of discharge at crest the flood of 1903 drops to fifth, being below those also of 1851 and 1858, both of which it passed in gauge height at St. Louis by reason of the contraction of the waterway and not so much by obstructions in the river as by the levees which encroached upon the flood-water section. In 1844 the flood plane extended from bluff to bluff, 7½ miles at site of Eads Bridge; in 1903 the flood plane had been contracted, principally by levees, to widths of about 3,500 feet at the Merchants Bridge and 2,000 feet at Eads Bridge.

The occurrence of another flood equal in volume to that of 1844 is by no means improbable. Although its height can be a matter of conjecture only, it was certainly not less than 6 feet above that of 1903 (or 44 feet on St. Louis gauge), since its recorded height is about that amount above the natural plane of 1903. The crest discharge of the flood of 1844 is estimated at 1,360,000 cubic feet per second. To determine the probable gauge height to which such a flood as that of 1844 would rise when confined by levees, practically, to the narrow channel afforded at the site of the Eads Bridge, reference is made to official reports stating the actual effects of this confinement on the flood of 1892 and the slightly greater one of 1903, where the following conclusion is reached:

> Since the flood of 1892 was forced from a probable height of 34.1 feet to 36 feet (1.9 feet) and the somewhat greater flood of 1903 from 35.3 feet to 38 feet (2.7 feet), it is safe to say that the enormously greater volume of a flood equal to that of 1844 will lift its crest at least 3.5 feet, or to the 45-foot mark upon the gauge.

> This plane is as low as can be risked, although it is above the level of the skew backs to the superstructure of the Eads Bridge, the lowest of which were placed at the flood plane of 1844 (41.4 feet above the zero gauge), and will submerge the lower ends of the steel arches.
>
> In order that the enormous volume of such a flood may pass the openings of this bridge below the plane of 45 feet with a velocity within limits of experience on the river great scour must take place on the sand deposit over the rock stratum upon which the bridge is founded. The cross section between the 45-foot plane and the sand bottom at ordinary stages is about 95,000 square feet. To pass through it a volume of 1,360,000 cubic feet per second would require a mean velocity of 14.3 feet per second, greater than has ever been measured in this river, and which would give a surface velocity of more than 12 miles per hour. To increase the cross section by complete scour to the 170,000 square feet available at the bedrock would reduce the mean velocity to 8 feet, an extraordinary but permissible rate of flow, but the probability is that the duration of the rise of the flood would be entirely too short to effect such great scour and that the crest volume would be forced through a cross section somewhat mean to these two and with a corresponding mean velocity of about 11 feet per second.

The above is summarized, the last three paragraphs quoted verbatim, from the report of Mr. William S. Mitchell, assistant engineer, dated December 2, 1905, and printed in the document. It must be noted particularly that in his opinion the 45-foot mark upon the gauge is as low as can be risked for a flood with a volume of that of 1844.

The officer in charge of the district, Maj. Casey, states that the railroad embankment on these lowlands, in conjunction with the two bridges crossing the river to St. Louis, form obstructions to the free flow of high floods and have materially raised the average height of these floods, as clearly shown by the fact that the great flood of 1903 while only the fifth in point of volume that has occurred within historic times was the third as regards height in feet on the St. Louis gauge. A plan is recommended for protecting the lowlands on the east side from excessive floods, involving a high levee extending from the northern limiting bluff, along the river bank to Prairie du Pont Creek, making use wherever practicable of railroad embankments and old levees., this levee at its southern end to extend easterly and northerly along a channel for the Cahokia Creek, the waters of which would go to the river through Prairie du Pont Creek. The assumed reference of the crest of the levees is 45 on the St. Louis gauge at that point, allowance being made at other points for a water slope of 0.6 foot per mile. The factor determining this height for levees was the flood of 1844, the crest of which registered 41.4. It was considered impossible to compute accurately the extra elevation due to the confinement of such a flood between the Illinois levees and the St. Louis shore, but an allowance of 3½ feet was thought to be probably on the safe side. Perhaps even this might not be sufficient allowance were it not for the fact that the river bottom along the reach considered was everywhere, as far as known, soft for at least 20 feet from the present bottom, and it was thought that with the increased velocity due to an excessive flood thus confined there would be very substantial scour of the river bottom, perhaps enough to neutralize a large part of the rise due to contraction alone. The plan recommended 53 miles of levees on the Illinois side and also 11 miles of levees on the Missouri side.

The report of the division engineer, Lieut. Col. Bixby, expressed the opinion that the constructions so made —

> will undoubtedly increase the height of the Mississippi floods in this locality, and thereby cause increased current velocities in the river, extra scour and damage to lands, excessive scour of river bed in this locality, with corresponding undesirable

bar deposits farther downstream, and extra difficulties to navigation during such floods, all to the detriment of navigation interests, so that it appears to me that the cost of such work should not be borne by the appropriation for the improvement of the Mississippi River, but should be borne either by the parties whose properties are to be thus protected, or by some special appropriation for protection of private properties.

It also appears to me that the direct and more proper method of "preventing floods by reason of obstructions" would be by removal of the obstructions themselves, instead of by addition of other obstructions. The obstructions to be thus removed would naturally be those which have been inserted since the river improvement has commenced, so far as such obstructions increase the height of floods in the river, and should include, first and foremost (*a*), all buildings and embankments which now stand in front of the United States established harbor lines; next (*b*) those between low-water line and freshet line, which are not absolute necessities to transportation and which interfere with the run-off of water. Under the latter head I consider railroad bridge piers and masonry abutments as necessary, but solid filled embankments as unnecessary, and I consider as especially unnecessary all other buildings and fillings which have been constructed in localities previously flooded by freshets.

In its report the Board of Engineers for Rivers and Harbors called attention to the fact that by improvement of the harbor of St. Louis, confining the low-water discharges to the channel in front of the city by closing the chutes behind the islands on the opposite bank and contracting its width to about 1,500 feet, an extensive area of land on the Illinois shore has been reclaimed and valuable property now in East St. Louis was formerly part of the river bed or low islands separated from the Illinois shore by the channel of the Mississippi. Constructions in this locality have reduced the natural width of the river from 6 miles to about 2,000 feet. The channel is further contracted by the piers and approaches of the bridges and there has resulted a material increase in flood heights. Referring to the effect of confining a flood such as that of 1844 in a channel 2,000 feet wide, it appears that it will require a mean velocity of 14 feet per second for the maximum discharge to pass through the present channel at Eads Bridge, with the water at an elevation of 45 on St. Louis gauge. If the flood causes a scour to bedrock, a distance of some 20 feet below the present river bottom, a mean velocity of 8 feet results, and the board considered that either assumption appears less probable than a material further increase in flood heights. The board was also of the opinion that it was not advisable for the United States to undertake any work in the "harbor and approaches to St. Louis with a view to preventing floods by reason of obstructions in the Mississippi River."

The Chief of Engineers, Gen. Mackenzie, concurred in the view that the work was not one which should be undertaken by the United States.

A number of citizens and property owners of East St. Louis and its vicinity formed an association, obtained the advice of engineers, and then secured legislation by the State of Illinois authorizing the appointment and organization of the East Side levee and sanitary district. This was effected early in 1909. Plans were adopted which include a diversion of Cahokia Creek directly from the bluffs to the Mississippi, at a point a little south from opposite the mouth of the Missouri, and a levee thence to Arsenal Island, opposite the southern part of the city of St. Louis. The funds are now being obtained through a general tax on all property in the district. A large amount of levee construction is now in progress. The levees are "in all places to be a minimum of 3.6 higher than the crest of the flood of 1844 and 7 feet above that of 1903." That is to say, the levees will be at the height of 45 on the St. Louis gauge at that point, and the slope is to conform to the plane of a 45-foot stage. The estimated cost of the improvement is $6,500,000. The assessed value of the property in the district to be protected is $57,000,000; the real value, $100,000,000.[1]

No dam should be designed which might cause a flood elevation of such height as to reach the top of the levees now under construction by the East Side levee and sanitary district, which levees are, as stated above, 3.6 feet higher than the plane of the flood of 1844. But some additional constructions have been made in and along the river since the date of the studies upon which the elevation of those levees was determined, and the levees now under construction may still more contract the flood widths.

These considerations and also the opinions expressed in the reports above outlined as to possible heights to which floods may reach under the conditions which exist in the harbor of St. Louis all lead to the conclusion that, if a dam should be built, it must be designed so that it would not cause an elevation of the crest of a flood of the volume of that of 1844 greater than that flood actually reached at the location of the dam. At the Steins Street location that was 424.6.

The general features of the river valley for some 20 miles below the Eads Bridge, including the depths to bed rock, have been outlined above and also the details of full cross sections at three characteristic locations. This covers the locality which may be considered in the wording of the act of Congress, as "at or near Jefferson Barracks." The construction of a dam at any point in this locality presents a very serious problem. The least objectionable location is that at the foot of Steins Street, where the depth to bed rock is about 15 feet less than at the other points. The works incident to the construction of a dam, such as those for the protection of low lands, for disposal of sewage and drainage, etc., would be less extensive and expensive at this point than at a lower location. The further consideration of this dam, its construction, and possible effect will be as at this point at the foot of Steins Street.

The dam must have considerable length in order to keep the flood waters at the elevation above indicated. Several lengths of dam and elevations of crest have been studied. In this connection the possible development of water power must be considered. This involves the construction of a power house, with installation of hydraulic and electric machinery and provisions for conducting water to and from the turbine wheels. There must also be a lock for the passage of boats. The elevation of the surface of a flood such as that of 1844, passing over the crest of the dam, must not be higher than 424.6. This last requirement can only be met by lowering the surface of such a flood below the dam, and this can only be done by excavation extending from the dam as far down the river as may be necessary to fully carry the water away.

A dam 5,000 feet long with crest at elevation 407.3 would pass the volume of the flood of 1844, with a depth on crest of 17.3 feet, thus filling the requirement of keeping the water of such a flood not higher than 424.6, but the surface elevation of such flood immediately below the dam must then be brought by excavation to the elevation 407.3.

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[1] Message of President H. D. Sexton, East Side levee and sanitary district, 1910.

The physical conditions at this site and the necessity of providing room for a power house and its appurtenances and for conducting water to and from the turbines are such as to make desirable a less length of dam.

With a length of dam of 4,000 feet the highest elevation of crest, which would not raise a flood such as that of 1844, higher than 424.6, would be 404.6. This would be an unsubmerged crest and the water surface below the dam at the time of such a flood should then also be 404.6. Other possible elevations of crest and of water surface below the dam, with resulting heads, are as follows:

Elevation of crest.	Water surface below dam, flood of 1844.	Head on wheels at flood of 1844.	Head on wheels with low water at 376.
404.6	404.6	20.0	28.6
403.0	411.9	12.7	27.0
402.0	413.8	10.8	26.0
401.0	414.9	9.7	25.0
400.0	416.2	8.4	24.0
399.0	411.2	7.4	23.0

The development of power in a commercially available form requires a regulated output of alternating electrical current. A substantially uniform speed of revolution of the electric generators is essential to the production of this current. This uniformity of speed can best be secured when there is very little or no variation in the head of water on the turbine wheels. Moderate reduction in the normal head reduces the output of power while maintaining uniformity of speed. Greater reduction of head makes it impossible to maintain the required speed of revolution and then the output of alternating current ceases. The extreme variation which is usually permitted occurs when the minimum head is from 55 to 60 per cent of the maximum head, but by appropriate design the range can be extended until the minimum head is from 40 to 45 per cent of the maximum, with a considerable loss, however, of efficiency at the high head.

This rule applies to the development of power by the same set of turbines through this range of variation of head. If greater variation must occur, a second set of turbines must be installed to secure an output of power continuous through all stages. Such additional provision of turbines, with the additional electric machinery and appurtenances, would materially increase the cost of power production. In either case extra turbines are required to give out the full amount of power at the lower heads.

In the present case a crest elevation of 401 with a head at extreme flood, as above shown, of 9.7 feet would determine for single sets of turbines a low-water surface elevation of 376, with a head of 25 feet, and thus maintain the range of variation of head substantially within the limits above defined. Installations of single sets of turbines would give continuous power output. The heads resulting from other crest elevations and with the low water at 376 are shown in the above table. All the conditions lead to the adoption for this dam of a length of 4,000 feet, a crest elevation of 401, and a flood-surface elevation below the dam of 414.9, involving such excavation from, and maintenance of, river channel as would prevent any greater flood elevation.

The use of a movable crest, or bear trap or other design, has been considered. In the determinations of height on crest as above given, a form of rounded crest has been adopted, giving a high coefficient of flow over the crest. This coefficient would be reduced for flow over a bear trap or movable crest and the crest elevation would become lower and the requisite excavation increased. There would be difficulty in manipulating a long movable crest of any substantial height, and any uncertainty in its operation at critical times might lead to serious flood effects. With a fixed crest, as above indicated, made sufficiently low to prevent undue elevation of floods, and in view of the considerations just stated, there seems to be no necessity for the installation of a movable crest.

Under the conditions outlined above, with an extreme low water flow of 35,000 feet per second and a head of 25 feet, there could be a development of 70,000 electrical horsepowers on the switchboard in the power house. If the low flow be taken at 40,000 cubic feet per second the power development would be about 79,000 electrical horsepowers on the switchboard.

As has been stated above, reduction in head reduces the output of current while maintaining within a certain range the requisite uniformity of speed. With the variation in head above assumed and with constant speed maintained, the output of power from a turbine would be one-half as great at the extreme low head as at the high head. Therefore, the number of turbines must be proportionately increased to maintain the full output at all stages. There must be twice as many turbines at this low head as would be required at the high head. This duplication of turbines may be made either by placing two turbines on one shaft, as has frequently been done, or by provision of separate turbines.

In a discussion given directly below of the slopes, velocities, and excavations in this channel between the suggested dam at Steins Street and the one near Commerce, there is included a description of a project which seems to have, in certain respects, better features than the others discussed. This one (the third) requires, however, a low-water elevation immediately below the Steins Street dam of 355. This would make the head at low water 46 feet, and the range between this head and the head of 10 feet at flood stages is too great for the installation of single sets of turbines. The installations could be in two ranges of variation in head, the one from 46 feet down to about 21 feet, the other from 10 feet up to about 21½ feet, these low heads being only 45 per cent of their respective high heads and thus within the allowable range of variation. Such an installation is practicable and its additional cost might be more than balanced by the increase of power and the decreased amounts of excavation and dredging demanded by this channel project. The power output would be 125,000 horsepowers with 35,000 second-feet and 146,000 horsepowers with 40,000 second-feet.

The effect, in the harbor of St. Louis, of building a dam at Steins Street with its crest at 401 would be a permanent elevation of the plane of low water of about 14 feet. The slopes of water surface and the velocity at all stages would be diminished, except at a flood of a volume equal to that of 1844. There would consequently be, at various stages, a deposition of part of the material carried by the Missouri River, which enters the Mississippi River within that part of the stream which would be affected by this dam. This would involve regulation and constant dredging to maintain the requisite area and depth of channel and to prevent flooding adjacent territory. These elements of the problem are considered at length in the report of the board.

The location of the other dam upon which this board is to consider and report is at or near Commerce. Several points in this neighborhood have been examined and two, in particular, have been studied. One is about a mile above Commerce, where an island and a comparatively high elevation of bedrock in a part of the channel afford fairly favorable conditions for construction. The requisite length could not, at this point, be had in line directly across the channel. A part of the dam would be on a line running somewhat diagonally downstream. The conditions as to foundations and construction would not be more difficult than at Steins Street. The other point studied is at Grays Point, about 6 miles above Commerce, where the conditions are also fairly favorable. They will be described directly.

The studies as to channel, slopes, velocities, etc., referred to below, indicate that in these respects the upper or Grays Point site is the more desirable. The natural channel immediately below Grays Point is such as to create a steep slope during the higher stages of the river and to seriously affect the regimen should the dam be placed near Commerce. A considerable part of the town of Thebes and all of the town of Graysboro would be permanently overflowed. The clearance under the railroad bridge at Thebes would be much diminished. Under all the conditions as now studied, the location at Grays Point is considered the better and is adopted in the studies and estimates.

The length assumed is 4,000 feet. The elevation of an unsubmerged crest would be 352.1, which is also the natural elevation at that point of the flood of 1844. The elevation at low water is 311.8. Possible elevations of submerged crest and resulting heads are as follows:

Elevation of crest.	Water surface below dam, flood of 1844.	Head at flood of 1844.	Head at low water.
352.1	352.1	20.0	40.3
343.0	352.0	12.5	31.2
340.3	352.0	10.8	28.5
338.2	352.0	9.7	26.4
335.9	352.0	7.4	24.1
333.9	352.0	6.4	22.1

For this dam a crest elevation of 343 with a head on turbines at extreme flood of 12.5 feet and a head at low water of 31.2 feet will give a variation of head within the limits above defined. Excavation in channel below the dam is not required.

With an extreme low-water flow of 35,000 second-feet and a head of 31.2 feet there could be a development of 86,000 electrical horsepowers on the switchboard in the power house. If the low flow be taken at 40,000 second-feet the power development would be 99,000 electrical horsepowers on the switchboard. The low flow is the measure of the continuous power output. It might be possible to equip this dam with a movable crest and thus create some storage and increase the power output, perhaps up to 125,000 horsepowers, but the objections to a movable crest of the great length of 4,000 feet have been above stated. In addition there would be a considerably increased expenditure, both for construction and for attendance.

CONSIDERATION OF RIVER CHANNEL FROM DAM AT STEINS STREET TO DAM AT GRAYS POINT.

A. *At extreme flood, as of 1844.*—The surface of this flood immediately below the dam at Steins Street is to be brought by the excavation above indicated to an elevation of 414.9. The surface of the same flood at the crest of the dam at Grays Point will be 364.6. There is thus a total fall in surface elevation of this extreme flood of 50.3 feet. Studies have been made by two methods of the possible slopes, excavations, and velocities of such a flood in this part of the river, about 125 miles in length; one method being by assuming a uniform slope between the two points and thus producing varying velocities at different localities, the other method by a variation of the surface slope and securing uniform velocity at all points for this flood. In both methods the bottom of the high-water channel is taken at an elevation of 376 at Steins Street, or 25 feet below the crest of that dam and with a uniform slope to the crest of the lower dam.

In a channel formed under the first method there would be a large deposit of silt in the lower reaches of this channel, the deposition diminishing in the parts farther upstream. In a channel formed by the second method the mean velocity of such a flood would be uniform at about 5¼ feet per second, and during such a flood there would be less deposition of silt. The amount of excavation required would be much greater than under the first method. The surface of the water also would be considerably higher in the lower reaches, involving greater outlay for levees and for damage and protection of lowlands.

A channel formed under either of these methods would consist with a workable development of power at Steins Street, provided, of course, the channel were maintained by dredging.

B. *A flood such as that of 1844 is of very infrequent occurrence.*—Study should be given more particularly to the conditions which occur frequently, as those of bank-full stage, or every year, as those of a stage of 26.7 on the St. Louis gauge, which is mean annual high water. At these stages the mean velocity in either channel above described would be reduced and would become about 3 to 4 feet per second, with a result of large depositions of silt at these as well as at lower stages, which would have to be removed by dredging, or else the high-water surface would be raised, increased damages would result, and the output of power at the Steins Street location would fail at high stages. The elevation above the Steins Street dam would be increased and the flood waters might be so raised as to overtop the East St. Louis levees.

A study has therefore been made of a third method with a view to such form of excavation as might secure increased velocities at bank-full or mean annual high-water stages, thus decreasing deposition at those and other stages.

In this study the slope at bank-full stage runs from an elevation of 354.7 at the dam at Grays Point to 398 at the dam at Steins Street, and is substantially a uniform slope with a velocity of from 4 to 6 feet per second. The low-water surface starts at the crest of the Grays Point Dam and runs to elevation 355 at Steins Street Dam. This elevation at Steins Street is determined from the method adopted for the form of excavation of channel, the depth of the excavation being increased relative to the width and thus securing greater velocities for the higher stages. The channel at low water would have a depth of 14.7 feet and a minimum width of 1,364 feet. The slope at low water would be nearly uniform and the velocity about 1¾ feet per second. Levees would be built, confining the waters of the highest flood to approximately the width of the present bank-full channel. The water surface of a flood of a volume such as that of 1844 would be at elevation 364.6 at dam at Grays Point and not higher than 414.9 at dam at Steins Street.

The form of channel and the slopes would be such as to give velocities at the various stages which will tend to reduce deposition of silt. No form of channel excavation has so far been found which will prevent silting at some stages and at some localities, but it is believed that a channel formed in the way just described would be as satisfactory as possible in this respect. An approximate estimate of the amount of excavation required for this channel is ten hundred million cubic yards. Regulation and bank protection will be required for the greater portion of this channel, and much dredging will be required for maintenance.

The channel at extreme low water would be by the first method 12.1 feet deep, by the second method 10.1 feet deep, and by the third method 14.7 feet deep.

The amount of excavation by the first method would be about 1,300,000,000 cubic yards, by the second method about the same, and by the third method about 1,000,000,000 cubic yards.

By the first and second methods the elevation of low water below the Steins Street Dam would be 376 and the electrical power on switchboard at Steins Street would be 70,000 horsepowers, with 35,000 second-feet and 79,000 horsepowers, with 40,000 second-feet. By the third method the low water below the Steins Street Dam would be at 355 and the electrical power on switchboard would be 125,000 horsepowers, with 35,000 second-feet, and 146,000 horsepowers, with 40,000 second feet.

This great increase of power by the third method is worthy of serious consideration. It would involve a much larger powerhouse and also a double installation of machinery, on account of the greatly increased range of variation in head. These requirements would considerably increase the cost. However, the capital cost per horsepower of electrical output would be much less and, from the power viewpoint, this would be the better method.

At the Steins Street location the west side of the river channel is formed by the rock bluff. In the rest and larger part of the channel the rock is covered. The depth of the channel at low water is from 7 to 17 feet. The conformation and the depths to bedrock are shown on the appended cross sections, plates Nos. 1 and 2. The figures given for the elevation of the bottom of the river above rock are those that existed at the time of taking these soundings, and (as in all parts of the Mississippi River) these elevations vary from time to time at different stages of the river. The surface of the ground from the river banks to the Illinois bluff is approximately level and from 20 to 30 feet above low water. The underlying rock surface varies from 77 feet below low water to 119 feet, the latter depth being near the Illinois bluff, in what may have been an ancient river channel; such ancient channel is also indicated in the section and borings taken near the Meramec River, 12 miles below.

Experience has shown that in this river any construction which even slightly affects the flow immediately also affects the shape of the channel. The great variations in volume of flow and the mobile character of the material overlying the rock render it impossible to secure sufficient stability in such material to make it a safe foundation for a heavy permanent structure. The comparatively small piers for bridges heretofore built in this river have caused deep scouring in the river bed. Whatever section might be finally adopted for a dam, it should be founded upon the underlying bedrock. The depth of this rock below the elevation of the water surface during ordinary stages, the great mass of mobile material overlying the bedrock, the enormous volume of water passing down the river, the frequent variations in volume and velocity of flow, and the provisions required to take care of this flow at every moment during the progress of the work, all make the problem of placing and securing foundations and of building the dam very serious.

The depth to bedrock is about 77 feet from the water surface at extreme low water, about 81 feet at what is called "standard" low water, and about 89½ feet at what is called mean stage, as far as can be anticipated from the result of borings, with possibly somewhat greater depths at some points. The three piers of the new municipal bridge recently built at St. Louis, with caissons under compressed air, are founded upon rock at depths of 55 feet, 85 feet, and 95 feet below extreme low water. Work in those caissons at the greater depth could only be carried on at very low stages of the river. At the extreme depths the pressure was such that a man was able to continue work only one hour at a time.

A number of methods for securing foundations have been considered. Whatever method might be adopted, the difficulties must be great, the time of construction long, the cost very large; but the construction is not impossible if sufficient money is provided.

The locks at Steins Street would be in two lifts on the Missouri side of the river, founded and partially cut into the rock bluff. The dimensions adopted by the board are 600 feet long, 110 feet wide. The difference of level between extreme low water below and extreme high water above the lock would be 69.6 feet on the basis of the project above described as No. 3. The dam would be straight, 4,000 feet long, on foundations going to bedrock. The power house may be at an angle with the line of the dam and extend downstream, with a length sufficient for the installation of power machinery as indicated above.

The power house must be founded upon bedrock. The intake or head bay is formed by masonry approach walls running 1,200 feet upstream, and also going to rock. The lower end of the head bay would be formed by a structure for transformers and other power appurtenances, this also founded on rock. The upstream end of the head bay approach walls would connect with a levee or embankment extending to the system of levees under construction by the East Side levee and sanitary district. From the downstream end of the power house a tailrace wall extends for a distance sufficient to afford bank protection.

At Grays Point the lock can be on the Missouri side, where a good location for it is found by cutting through a depression in the rock bluff. The dam would be substantially perpendicular to the axis of the lock and extend 4,000 feet across the thread of the stream. The power house would extend at an angle with the line of the dam. Its lower end would be connected with the rock on the Illinois bank, this connection serving as the foundation for a structure for transformers and other power appurtenances. All these structures would be founded on rock. The upper boundary of the head bay would be formed by a wall connecting with the rock face on the Illinois bank and extending diagonally upstream to a connection with the levee forming the eastern boundary of the new channel for the river. Provision would be made for the passage of water from the lowlands above the head bay by construction of a conduit passing under the transformer house.

By the construction of the dam at Grays Point and the form of channel above suggested, the elevations of water surface at all stages would be permanently raised as far up the river as East Kaskaskia, about 70 miles above Grays Point. Above this the water surfaces will be lowered, the maximum depression being at the Steins Street Dam. Levees will be required along both banks of the flood channel, except where the bluffs—particularly on the Missouri side—may make the levees unnecessary. Particular attention should be given to the closure of the head of the St. Francis Basin against the increased elevations in the river.

A diversion channel would be required for Big Muddy River, with levees on each side up to the Illinois bluffs.

Levees running to the highlands would be necessary for the Kaskaskia River and for other smaller streams.

Pumping stations would be required for each inclosed area, of sufficient capacity to take care of rainfall and subsidiary drainage; canals or ditches would be requisite to carry the water to the pumping stations.

At a number of points changes would be necessary in the elevation or location of railroads and at some places new bridges would be required, as at Muddy River.

The Mississippi River between the mouth of the Ohio and the lower dam above referred to is not discussed in this paper because it does not become necessary to lower the river bed below that dam in order to secure a power development.

The power production at the lower dam would be, as stated above, about 100,000 electrical horsepowers, the minimum head being 12½ feet; this low head would occur only in the event of a flood equal in volume to that of 1844. The power output at the St. Louis dam would be about 150,000 electrical horsepowers with heads from 46 down to about 12 feet. At the moment of occurrence of the crest of a flood of the volume of that of 1844 the head might be reduced to

10 feet; but the reduction in power, if such a flood should recur, would not be great and would last a very short time. This observation applies to the power at each dam.

The estimated cost of the two dams, locks, power houses, approach walls, guard walls, and excavations in head bays, with the hydraulic and electric installations, is $86,582,000, as shown in the following estimate, the unit prices in which have been adopted by the board.

Dam at Steins Street:		
908,000 cubic yards concrete, at $25	$22,700,000	
65,800 cubic yards concrete, at $10	658,000	
		$23,358,000
Lock:		
242,000 cubic yards excavation of rock, at $2	484,000	
110,650 cubic yards concrete, at $6	663,900	
Gates and operating machinery	600,000	
		1,747,900
Approach walls:		
Upstream 26,000 cubic yards concrete, at $6	156,000	
Downstream, 103,900 cubic yards, at $6	623,400	
		779,400
Head and tail race walls, 181,620 cubic yards concrete, at $20		3,632,200
Excavations in head bay and above dam, 8,852,000 cubic yards, at 35 cents		3,098,200
Power house and transformer house:		
Substructures, 417,120 cubic yards concrete, at $20	8,342,400	
306,240 cubic yards concrete, at $10	3,062,400	
Superstructures, transformer, and switchboard compartments, galleries, offices	1,400,000	
		12,804,800
Installation—		
Hydraulic	6,600,000	
Electric	4,050,000	
		10,650,000
		56,070,500
Contingencies and supervision 5 per cent		2,803,500
Total at Steins Street		58,874,000
Dam at Grays Point:		
468,000 cubic yards concrete, at $20	9,360,000	
116,080 cubic yards concrete, at $10	1,160,000	
		10,520,000
Lock, including approach walls:		
901,750 cubic yards excavation of rock, at $2	1,803,500	
166,450 cubic yards excavation, at $6	998,700	
Gates and operating machinery	270,000	
		3,072,200
Head and tail race walls, 357,500 cubic yards concrete, at $6		2,145,000
Excavations in head bay and above dam, 2,400,000 cubic yards, at 35 cents		840,000
Power house and transformer house:		
Substructure, 208,560 cubic yards concrete, at $20	4,171,200	
153,120 cubic yards concrete, at $10	1,531,200	
Superstructure, transformer, and switchboard compartments, galleries, offices	429,000	
		6,131,400
Installations—		
Hydraulic	2,000,000	
Electric	1,680,000	
		3,680,000
		26,388,600
Contingencies and supervision 5 per cent		1,319,400
Total at Grays Point		27,708,000

For the two locations:	
At Steins Street	$58, 874, 000
At Grays Point	27, 708, 000
Total	86, 582, 000

The estimated cost of the excavations for channel between the dams, for regulation of the channels above the Steins Street Dam and from Steins Street to the lower dam, for levee constructions above Steins Street and from Steins Street to the lower dam and for changes in and new bridges for railroads is $341,631,800, as shown by the following estimate, the figures in which have been adopted by the board:

Channel between the two dams, dredging and moving material beyond the channel limits, including rehandling and provision for dumping ground, 750,000,000 cubic yards, at 25 cents	$187, 500, 000
Regulation of channel:	
Above Steins Street	7, 220, 000
From Steins Street to Grays Point	18, 000, 000
Levee construction:	
Above Steins Street	8, 364, 000
Between Steins Street and Grays Point	6, 433, 000
Raising railroad above flood line	2, 608, 500
	230, 125, 500
Contingencies and supervision, 5 per cent	11, 506, 300
	241, 631, 800
The cost of removal of the sediment which would be deposited by the river during the construction of the dams and channel is not included in the above estimate. This cost would depend upon the rapidity with which the channel was built. The board considers (see report of board) that the increase in cost from this item alone would be not less than	100, 000, 000
	341, 631, 800

SUMMARY.

Steins Street Dam, lock, power installation, etc	58, 874, 000
Grays Point Dam, lock, power installation, etc	27, 708, 000
Channel, levees, regulation, etc	341, 631, 800
	428, 213, 800

The results of the construction of these two dams and of the excavations, levees, and other works incident to the construction of the dams and the formation of such a channel between them as would be required to prevent flood damages and to minimize as far as practicable the depositions of silt would be:

A. A low-water channel of not less than 14 feet depth from near the mouth of the Illinois River to Grays Point, which is 45 miles above the mouth of the Ohio.

B. The development of about 150,000 electrical horsepowers at St. Louis and about 100,000 electrical horsepowers at Grays Point, about 135 miles below St. Louis.

The cost would be approximately $428,200,000.

There would also be required an annual expenditure for maintenance, including dredging and such works of regulations as experience from year to year would indicate to be necessary.

The electrical power would be, as expressed in the act of Congress, "incidentally created by the dams." The money or capital value of a particular development depends, to a great extent, upon its location, upon the price of coal which can be used to develop power, the supply of power from other developments, and the existing and probable future demand for power.

At St. Louis the cost of coal is low. A large power development is in progress and partly completed at Keokuk on the Mississippi River. The transmission lines from Keokuk have been constructed to St. Louis; contracts have been made for the sale and use of a large amount of power in that city, and a considerable amount of power is already being delivered. This seriously effects the question of the value of another hydroelectric development at or near St. Louis.

JOHN BOGART.

APPENDIX NO. 1 TO APPENDIX D.

COMMUNICATIONS FROM THE LAKES-TO-THE-GULF DEEP WATERWAY ASSOCIATION.

MEMORANDUM FROM MR. LYMAN E. COOLEY, ST. LOUIS, OCTOBER 26, 1910.

THE MIDDLE MISSISSIPPI, GRAFTON TO CAIRO.

From the mouth of the Illinois River to the mouth of the Ohio River is a distance of 212 miles, with a fall at normal low water of 132 feet and an average declivity of 0.622 foot per mile.

Memphis datum, 412.4 feet at Grafton to 280.5 feet at Cairo.
Chicago datum, 174.6 feet at Grafton to 306.5 feet at Cairo.
Gulf level, 405.6 feet at Grafton to 273.7 feet at Cairo.

VOLUME AND DURATION OF STAGES.

Only a limited territory is tributary below the mouth of the Missouri River. The St. Louis gauge is therefore taken as the criterion for this division. The following table gives height on gauge, volume in second-feet, and duration of characteristic stages.

St. Louis gauge.

[Average of 48 years.]

Gauge reading.	Volume.	Days below.	Remarks.
0	34,000	1	Normal low water.
1	41,000	1.2	Water-power basis.
2	48,000	6.5	
3	56,000	13	
4	64,000	29	Standard low water.
5	73,000	49	Above for 11 months.
6	82,000	71	
7	92,000	92	Above for 9 months.
8	102,000	111	
8.43	106,000	120	Above for 8 months.
25.5	435,000	[1] 14.2	Mean of highest daily stages.
30	606,000	[1] 2	Bank-full stage.
38	950,000	....	Flood of 1903.
41.3	1,360,000	....	Flood of 1844.

Days above.

The Sanitary and Ship Canal of Chicago adds 14,000 second-feet.[1] The Illinois and Michigan Canal can add 1,000 feet additional.

Extreme high water, as in 1844 and 1903, occurs perhaps twice in a century, but must be reckoned with in constructing embankments and provision made for these volumes at structures.

The significant high water is the bank-full stage, above which the water has ranged only 80 days in 40 years. A significant low water is at 1 foot on the gauge with a volume of 41,000 second-feet, below which the water has ranged for 48 days in 40 years.

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[1] Note by Engineer Board: Only 4,167 second-feet has, up to 1913, been authorized by the War Department, and even this only conditionally upon an approval of Congress, not yet given.

The low-water volume of 41,000 second-feet will be raised to 55,000 second-feet when the Chicago Sanitary and Ship Canal is operated to its fullest capacity.

PROJECT.

Two dams are proposed which, together with changes in the river bed below, will greatly reduce the declivity and enable a large depth to be obtained for navigation. A free fall at each dam will be produced between the significant stages hereinbefore stated and a large water power made incidentally available. One of these dams is to be located from 7 to 12 miles below the Eads Bridge at St. Louis and the other in the vicinity of Commerce, some 36 miles above the confluence of the Ohio River.

A fixed dam in combination with bear-trap sections is to pass the bank-full stage with a depth on crest of 10 feet or less, and greater floods within desirable limits.

ST. LOUIS DAM.

Bedrock at a suitable elevation is found 8 miles below the Eads Bridge and above Jefferson Barracks, or 45 miles below Grafton. Comprehensive borings may develop a site farther downstream.

The crest of the dam is to be at elevation 413 feet Memphis datum, or 26 feet on gauge at St. Louis. This is 0.6 foot above normal low-water level at Grafton, and low water will there be raised by about 4 feet.

The following stages refer to proposed crest of dam:

	Jefferson Barracks.	St. Louis.
Normal low water below	28.4	25.9
Bank-full stage	−1.8	4.1
High water, 1844, above	9.5	15.4

The high water of 1844 at Chain of Rocks 10 miles above Eads Bridge, is 21 feet and at Grafton 30.1 feet above crest of dam.

It is proposed to lower the river bed below the dam by 12 feet or more at the outset, thus giving a free fall at all stages of water and a low water head of more than 40 feet. This will make flood stages above the dam independent of back water and strictly subject to the dam.

Official reports suggest an enlargement of the cross section through St. Louis harbor in order to mitigate flood slopes. Such treatment is also desirable in connection with proposed dam.

The results will be—

1. A pool extending 45 miles to the mouth of the Illinois River at Grafton, and farther up the Mississippi, and also half way up to St. Charles on the Missouri River.
2. A harbor with a low-water depth of 30 feet and more for the cities of St. Louis and East St. Louis with a flood range of 10 to 15 feet, without accentuating extreme high-water limit above St. Louis.
3. An available water power of 200,000 horsepower (constant and effective and measured on the turbine shaft), from low-water to bank-full stage.

COMMERCE DAM.

Bedrock is found at varying elevations in and below the gorge extending from Grays Point to Commerce, and the sight may be taken provisionally at Commerce, 36 miles above the confluence of the Ohio River and 131 miles below the St. Louis dam.

The crest is to be at elevation 343 feet Memphis datum, or 70 feet below the crest of the St. Louis dam.

The following stages of water refer to crest of dam:

	Commerce.	Cairo.
Normal low water below	32.0	62.5
Bank-full stage below	10.3	27.6
High water 1844 below	1.8	18.5

The depth on crest of dam is to be limited as proposed for the St. Louis dam. The dam will have a free fall at all stages. High water will be materially increased as far up as Grand Tower, 40 miles above Commerce. Some 60,000 acres will be damaged, but this area can be protected by an embankment and made more valuable than at present. An embankment will also be required to close the St. Francis front below Cape Girardeau.

The low-water declivity between Commerce and Cairo is very steep, and this may be lowered at Commerce by more than 8 feet at the outset, thus giving a head at the dam of more than 40 feet.

The results will be:

1. A low-water pool extending upstream nearly to Chester, or half way to the St. Louis dam.
2. A low-water fall of 30 feet between the two dams in lieu of the present fall of 73.6 feet, thus promoting easy regulation for a depth of 14 feet or more.
3. Lower declivity below Commerce, thus making easy regulation to this reach.
4. An available water power of 200,000 horsepower, the same as for the St. Louis dam.

Estimate.

Including the locks, 1,000 by 110 feet, and for an ultimate depth of 24-foot channel for present depth of 14 feet, embankment, etc., and not including water-power structures and installation	$40,000,000
No detail estimates have been made, and the above is to be taken with a plus uncertainty of 25 per cent.	
The official estimate for the lock and wicket-dam scheme, including dam and canal above St. Louis, is, in round numbers	32,000,000
The official estimate for the open-channel treatment, together with the dam and canal above St. Louis, is, in round numbers	60,000,000

Neither of these schemes lend themselves to progressive development to depths greater than 14 feet.

ULTIMATE DEVELOPMENT.

Regulation and development for an ultimate depth of 24 feet will lower the declivity between the dams and below Commerce, and the head for this condition is taken at 55 feet for each dam.

Conservation of water resources will in time increase the flow, and the volume is taken as 80,000 second-feet in lieu of 55,000 feet.

The available water power will then be 400,000 horsepower at each site.

The cut-off at Greenfield bend now threatens Cairo. This can be so directed as to shorten the river by 12 miles and leave an ideal harbor site for Cairo. The river below Commerce will thus be reduced to a length of 24 miles. The improvement of the river below Cairo will lower the river bed. These causes will produce very difficult slopes between Cairo and Commerce, which can be taken out in increased head at Commerce Dam.

LYMAN E. COOLEY.

JANUARY 26, 1910.
Checked February 8, 1910.

SUPPLEMENTAL MEMORANDUM.

WATER POWER WITH STEAM AUXILIARY.

The record of 40 years shows that the natural flow has been less than 92,000 second-feet for an average of 92 days per year. With steam auxiliary for this period an additional 51,000 second-feet may be utilized, thus giving an additional horsepower at each site as follows:

	Horsepower.
40 feet head	185,000
55 feet head	255,000

MISSISSIPPI-OHIO COMBINATION.

The low-water flow of the Ohio River corresponding to 41,000 feet in the Mississippi is taken at 25,000 second-feet. The sum of the two is 66,000 second-feet, when as a matter of fact the corresponding flow in the Mississippi below Cairo is 100,000 second-feet, or 50 per cent greater. This is due to lack of parallelism in stages and to lack of coincidence in low-water years between the western and eastern water systems which combine in the lower Mississippi.

Bedrock is reported in the Ohio River at Mound City and above. No investigation has been made to determine the feasibility of constructing a dam across the Ohio at the same elevation as proposed for the Mississippi at Commerce. If such dam be feasible, then by means of a canal connecting the two sites, it will be practicable to utilize the combined flow or 100,000 second-feet, thus giving power 50 per cent in excess of that which could be produced by treating each site separately.

With the increment of 14,000 second-feet from Lake Michigan and under 55 feet head, 570,000 horsepower could be produced at the combined sites, and still more as the flow shall be increased through conservation of water resources.

Deep water would be backed up in the Ohio River to Evansville, Ind., and a valuable high-level connection would be made between the Ohio and Middle Mississippi.

LYMAN E. COOLEY.

FEBRUARY, 1910.

NOTE.—The significant low-water volume herein taken for water-power estimates is 41,000 second-feet at a stage of 1 foot on the St. Louis gauge, and corresponds to 25,000 second-feet in the Ohio River at Paducah and to 100,000 second-feet in the Mississippi River below Cairo.

The elevations (Memphis datum) corresponding thereto are as follows:

Grafton	412.8
St. Louis gauge	388.1
Jefferson Barracks	385.4
Commerce	311.7
Cairo	282.0

L. E. COOLEY.

FEBRUARY, 1910.

LETTER FROM MR. LYMAN E. COOLEY.

CHICAGO, *November 3, 1910.*

Gen. W. H. BIXBY,
Chief of Engineers, United States Army,
Washington, D. C.

GENERAL: I inclose herewith memorandum No. 2, which covers certain specific questions asked me at the hearing before the board at St. Louis October 26, 1910.

This is an extension of the memorandum furnished at the hearing. I send also separate inclosure, copy [1] of profile, Exhibit No. 9, referred to in above documents.

For the Lakes to the Gulf Deep Waterway Association.

Very respectfully,

LYMAN E. COOLEY,
Consulting Engineer.

MEMORANDA NO. 2.

THE MIDDLE MISSISSIPPI—GRAFTON TO CAIRO.

Amplification of memoranda made under date of January 26 and February 8, 1910, to cover specific points raised at the hearing before the Board of Engineers on October 26, 1910, and other related questions. Prepared from blotter notes of studies made in winter of 1909–10, with revisions to date.

Chicago, October 31, 1910.

PROFILE: EXHIBIT NO. 9.

On this profile are shown in red locations and elevations of the two dams as discussed for St. Louis and Commerce.

The flow lines for the conditions to be immediately produced are also shown in red. The high-water line corresponds to 606,000 second-feet, the equivalent of the bank full stage and is taken at 10 feet on the crest of both dams, and also at 10 feet below crest of St. Louis dam. The low-water line corresponds to 55,000 second-feet and is taken at crest and 40 feet below for each dam.

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[1] Not printed.

The slopes are figured in short reaches, the ratio of new to natural slopes being taken in the inverse ratio of the cubes of the mean depth. The results are approximate and change with changing regimen and are intended to be illustrative.

THE DAMS.

Each dam is projected for a spillway length of 4,000 feet of which 3,000 feet is to be fixed weir and 1,000 feet is to consist of bear-trap sections with a range of 15 to 16 feet below fixed weir level.

The bear-trap sections are to be located athwart the stream. The fixed spillway is to be an equilateral slant form upstream. Apex inclosing 60°, thus giving double the length of distance athwart the stream.

The net length of dam athwart the stream is therefore 2,500 feet, and with piers may be taken at 2,640 feet, or one-half mile from out to out between abutments.

The arrangement of bear-traps and fixed spillways can be varied to suit conditions as for a bridge and for ice and drift passes.

WATER POWER AND LOCATION.

For a St. Louis site the lock is taken on bluff or Missouri side, same to be placed above line of dam. On east or Illinois side above dam, construct at outset a chambered shore wall to rock 1,500 to 2,000 feet long, with tailrace behind for water-power installation. For a dam erected at or near quarantine, it may be feasible to cut a canal to the Meramec Valley for future development; otherwise a longer shore wall on east side may be expedient.

For Commerce, short head races from dam down stream suggest themselves, to be constructed largely at future convenience. A site which will permit a future canal at pool level to the Ohio River also suggests itself.

CAPACITY OF DAM.

The length of crest is 4,000 feet (bear-traps up). Ten feet on dam will give approximately 480,000 second-feet. The water power installed and adjuncts should give 140,000 second-feet additional. The total is 620,000 second-feet, which is the equivalent of the bank-full stage 606,000 second-feet plus 14,000 second-feet contributed at Chicago. With bear-trap dams down 380,000 second-feet will be added, making a total of 1,000,000 second-feet for a limit of 10 feet on dam. This covers all known floods except that of 1844 with estimated volume of 1,360,000 second-feet. An additional depth of $2\frac{1}{2}$ feet on dam will pass about 230,000 second-feet additional and a second power installation will be adequate to the remainder. Adequate provision can be made, or damage can be suffered once in a century or two, provided disaster is not invited.

THE RIVER BED.

The river bed is to be immediately lowered below the St. Louis Dam, so as to produce a low-water elevation (55,000 second-feet) of 40 feet below crest. This involves the removal of about 100,000,000 yards for a lowering of 12 feet at the dam and running out 40 miles below. The width at the new level is taken at 2,235 feet, the declivity at 0.30 feet per mile, and the mean depth at 12 feet.

The river bed below Commerce is also to be lowered so as to bring the low-water line 40 feet below crest. This involves the removal of about 25,000,000 yards for the lowering of 8 feet at dam, running out 16 miles below. The declivity will be nearly 0.60 feet per mile.

The lowering of the river bed is to be effected by systematic regulation in combination with hydraulic dredging. The lines are to conform to the ultimate channel lines and this initial work is to be taken as a step toward the final channel.

THE THEORETICAL CHANNEL.

Preliminary consideration by short methods has been given the channel between the two dams for the purpose of fixing limits and as a basis for final study.

The bank-full volume is taken at 620,000 second-feet (606,000 and 14,000).

The declivity is taken from elevation 25 feet below St. Louis Dam to 10 feet above Commerce Dam, a fall of 35 feet, uniformly distributed.

The cross-section has a uniform width of 2,550 feet, a uniform area of 110,000 square feet, and a uniform mean depth of $43\frac{1}{3}$ feet. A parabolic form of section is assumed in which the area at St. Louis Dam is taken at two-thirds the product of width by depth, changing systematically to thirteen-fifteenths of the product of width by depth at Commerce. The depth will therefore be 65 feet, or 90 feet below crest of St. Louis Dam and 50 feet or 40 feet below crest of Commerce Dam. The bottom of the channel will have a declivity of 20 feet.

The theoretical section gives a width of 3,000 feet at elevation of crest of St. Louis dam, and this is taken as the proper river limit for extreme high water.

The low-water channel is taken with a depth of 30 feet and a mean depth of 20 feet, or 60 feet below crest of St. Louis dam, thus giving a width at this level of 1,733 feet and a cross-section of 34,660 square feet. The volume required is about 80,000 second-feet.

The low-water channel expands downstream and will have a width of about 2,116 feet and a depth of about 32–33 feet, midway between St. Louis and Commerce. At Commerce the theoretical depth will be 40 feet, mean depth 34⅔ feet, and width 2,465 feet at low water. The slope is a curved line running from the crest of the Commerce dam to 60 feet below crest of St. Louis dam, as before given.

In the trial channel herein assumed, widths and slopes can be estimated for other volumes.

PROBABLE RESULTS.

The foregoing for an ultimate channel indicates:

1. That the flood of 1844 can be provided for at a level below the proposed crest of the St. Louis dam and within a bank limit of 3,000 feet.
2. That the bank-full limit, or 620,000 second-feet, will have an elevation of 25 to 30 feet below crest of St. Louis dam.
3. That low water may be taken at 55 to 60 feet below crest of St. Louis dam for a volume of 80,000 to 90,000 second-feet. A channel of 24 feet is thus determined.

Variation in coefficients and in hydraulic elements account for above variation in results.

CHANGE IN REGIMEN.

The distance between the two dams is divisible into three characteristic reaches of nearly equal length.

The lower reach is a pool section, to be so treated as to direct the silting up of dead area.

The middle reach is to be treated as largely a problem of regulation.

The upper reach is a problem of sinking the river bed, to be worked out by regulation combined with hydraulic dredging and requiring time for the consummation.

The changes should be progressive and conform to the lines determined for the ultimate channel.

In practice there may be endless modification and variation in detail without impairing the desired regimen as a whole. Some of these will disclose themselves in the final and detail studies.

LYMAN E. COOLEY.

CHICAGO, *October 31, 1910.*

APPENDIX E.

[House Doc. No. 1061, 61st Cong., 3d Sess.]

WATERWAY FROM LOCKPORT, ILLINOIS, TO THE MOUTH OF THE ILLINOIS RIVER.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING,

WITH A LETTER FROM THE CHIEF OF ENGINEERS, REPORT OF A BOARD OF ENGINEERS ON AN EXAMINATION OF THE WATERWAY FROM LOCKPORT, ILLINOIS, BY WAY OF THE DES PLAINES AND ILLINOIS RIVERS, TO THE MOUTH OF SAID ILLINOIS RIVER, AND CERTAIN RELATED SUBJECTS.

DECEMBER 5, 1910.—Referred to the Committee on Rivers and Harbors and ordered to be printed.

WAR DEPARTMENT,
Washington, December 5, 1910.

SIR: I have the honor to transmit herewith a letter from the Chief of Engineers, U. S. Army, dated 1st instant, together with a preliminary report made by the special Board of Engineers appointed in pursuance of the river and harbor act of June 25, 1910, to consider and report upon a waterway from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River, and certain related subjects.

Very respectfully,

J. M. DICKINSON,
Secretary of War.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, December 1, 1910.

SIR: I have the honor to submit herewith, for transmission to Congress, a preliminary report dated November 1, 1910, made by the special Board of Engineers appointed in pursuance of the river and harbor act approved June 25, 1910, to consider and report upon a waterway from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River, and certain related subjects.

Very respectfully,
W. H. Bixby,
Chief of Engineers, U. S. Army.

The Secretary of War.

PRELIMINARY REPORT ON WATERWAY FROM LOCKPORT, ILLINOIS, TO MOUTH OF ILLINOIS RIVER.

War Department,
Office of the Chief of Engineers,
Washington, November 1, 1910.

Sir: The Board of Engineers appointed by the Secretary of War September 8, 1910, Special Orders, No. 43, Office of the Chief of Engineers, current series, for the consideration of a "waterway from Lockport, Ill., by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River," has the honor to submit the following report.

The provisions of the law under which the Board is acting are contained in section 1 of the river and harbor act approved June 25, 1910, and are as follows:

> For the construction of a waterway from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River, one million dollars. The Secretary of War shall appoint a board of five members, to be composed of four engineer officers of the army and one civil engineer taken from civil life. The president of the board of five members authorized under act of March second, nineteen hundred and seven, to examine the Mississippi River below Saint Louis and report to Congress on the project of a fourteen-foot channel, shall be a member of and president of the board herein provided for. Said board shall report upon the feasibility of such waterway and the most advisable depth and dimensions therefor, in case the same is recommended; also upon such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose; and further, also, upon the influence on volume and height of waters in the Mississippi River below Cairo; and further, also, as to the effect upon the climate of the Lake States by a change in the natural currents of Lake Michigan.
>
> The Board shall, after full conference with the authorized agency of the State of Illinois, submit a report upon the extent to which the United States may properly cooperate with the State of Illinois in securing the construction of a navigable waterway from Lockport to the mouth of the Illinois River in conjunction with the development of water power by said State between Lockport and Utica, for which the people of the State of Illinois have authorized their general assembly to appropriate twenty million dollars; the report shall state the extent and character of the cooperation recommended and the conditions considered necessary in connection therewith to fully protect the interests of the United States. Should the Board consider cooperation to be advisable, the report herein called for shall include plans and estimates of cost of the work recommended to be done by the United States alone or in cooperation with the State of Illinois; and until these plans and estimates have been submitted and a project for the improvement adopted by Congress the appropriation of one million dollars herein made shall not be available for expenditure. The Board also shall consider and report upon the improvement of the Mississippi between the mouth of the Illinois River and the mouth of the Ohio River by the construction of a dam at or near Jefferson Barracks and a dam at or near Commerce, and the development of water power incidentally created by such dams. In the performance of its duties the Board may consider all reports heretofore made; and the force, plant, and records of the Mississippi River Commission and the several engineer districts between Chicago and Cairo shall be available for the use of the Board.

The Board assembled at Washington, D. C., September 14, 1910, to organize, and then provided for collecting the data required to determine the question before it and arranged for a conference with the authorized agency of the State of Illinois.

In accordance with arrangements made with the governor of Illinois, the Board again assembled at Chicago on October 19 for conference with Mr. Isham Randolph, chairman of the Internal Improvement Association of the State of Illinois, who had been designated by the governor as the authorized agency of the State. After a short conference with Mr. Randolph the Board made an inspection of the canal and other works of the Sanitary District of Chicago and of the sites for proposed power dams on the Des Plaines and Illinois Rivers suggested by the Internal Improvement Commission of Illinois. The Board then made a trip down the Illinois and Mississippi Rivers from La Salle, Ill., to Cairo, during which inspection was made of the existing river channels, the State and Government locks and dams of the Illinois River and the sites proposed for dams on the Mississippi River above Cairo. Mr. Randolph accompanied the Board on these inspections from Chicago as far as Thebes, Ill.

From Cairo the Board returned to St. Louis, where, by appointment, Mr. Lyman E. Cooley, consulting engineer for the Lakes to the Gulf Deep Waterway Association, appeared before it and explained his plans for the improvement of the Mississippi River from the mouth of the Illinois River to Cairo. He also promised to furnish the Board certain data and studies with reference to these plans.

The Board is now considering and discussing all available data and information bearing upon the feasibility of the proposed waterway and its most advisable depth and dimensions. The extent to which the United States may cooperate with the State of Illinois in securing this waterway and the character of such cooperation can be determined only when the final plans of the State of Illinois have been presented to the Board. The preliminary plans presented by Mr. Randolph have been discussed with him, and are to be followed by further communication at an early date from the State of Illinois. Decision as to all these matters may to a certain extent depend upon the definite project and proposal to be presented by the State.

Until the preceding questions are decided and the volume of water to be diverted from Lake Michigan is known it is impracticable to report definitely upon "such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said lakes," etc., and "upon the influence on volume and height of waters in the Mississippi River below Cairo." Studies of these questions are now being made.

The effect produced upon the climate of the Lake States by a change in the natural currents of Lake Michigan is a new issue, which requires original investigation of matters hitherto untouched anywhere, and is now progressing.

Immediately after its organization the Board, through one of its members, initiated the careful examination of the substrata at and near the sites of the dams proposed to be built near Jefferson Barracks and near Commerce. Dams of such magnitude, under the trying conditions to be expected on the Mississippi River at the proposed sites, are practically without precedent, and until further information is secured the Board is unable to render concerning them any opinion of conclusive character.

Pending the completion of negotiations with the authorized agency of the State of Illinois and the receipt of further data upon other matters under consideration, the Board finds that the above preliminary report is all that can be submitted at the present time, but it expects that a further report, covering at least the more important subjects named in the act, can be submitted for consideration by Congress during its present session.

Respectfully submitted.

W. H. Bixby,
Brig. Gen., Chief of Engineers, United States Army.
C. McD. Townsend,
Colonel, Corps of Engineers.
C. Keller,
Major, Corps of Engineers.
J. B. Cavanaugh,
Major, Corps of Engineers.
John Bogart,
Civil Engineer.

[Second indorsement.]

The Board of Engineers for Rivers and Harbors,
Washington, November 26, 1910.

Respectfully returned to the Chief of Engineers, U. S. Army.

It appears to have been impracticable, on account of the limited time available, for the special Board submitting the within report to incorporate therein its final views upon the several questions upon which it is required to report. It is stated that investigations and accumulation of data are in progress, and that it is expected that a further report will be submitted during the coming session of Congress. Until such further report has been received, this Board can express no opinion regarding the several questions involved, and it recommends that the within preliminary report be forwarded for the information of Congress.

For the Board:

Dan C. Kingman,
Colonel, Corps of Engineers,
Senior Member Present.

APPENDIX F.

[House Doc. No. 1374, 61st Cong., 3d Sess.]

WATERWAY FROM LOCKPORT, ILL., TO THE MOUTH OF THE ILLINOIS RIVER.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING,

WITH A LETTER FROM THE CHIEF OF ENGINEERS, REPORT BY A SPECIAL BOARD OF ENGINEERS UPON A WATERWAY FROM LOCKPORT, ILL., BY WAY OF THE DES PLAINES AND ILLINOIS RIVERS, TO THE MOUTH OF SAID ILLINOIS RIVER, AND CERTAIN RELATED SUBJECTS.

FEBRUARY 10, 1911.—Referred to the Committee on Rivers and Harbors and ordered to be printed.

WAR DEPARTMENT,
Washington, February 9, 1911.

SIR: I have the honor to transmit herewith a letter from the Chief of Engineers, U. S. Army, of this date, together with copy of report made by a special Board of Engineers appointed in pursuance of the river and harbor act approved June 25, 1910, to consider and report upon a waterway from Lockport, Ill., by way of the Des Plaines and Illinois rivers, to the mouth of the Illinois River, and certain related subjects.

Very respectfully,

J. M. DICKINSON,
Secretary of War.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, February 9, 1911.

SIR: I have the honor to submit herewith, for transmission to Congress, report dated January 23, 1911, made by the special Board of Engineers appointed in pursuance of the river and harbor act approved June 25, 1910, to consider and report upon a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers to the mouth of Illinois River, and certain related subjects.

This report has been referred to the Board of Engineers for Rivers and Harbors for review, as required by law, and in its report this Board concurs in general with the special Board in its conclusions concerning the waterway from Lockport to the mouth of the Illinois River. The only essential difference between the views of the two boards is upon the extent of cooperation by the United States in the construction of the portion of the waterway between Lockport and Utica. In the opinion of the Board of Engineers for Rivers and Harbors no expenditures for construction should be made by the United States on this section of the waterway. In the opinion of the special Board the $20,000,000 authorized to be appropriated by the State should be sufficient to entirely complete this section of the waterway, including the locks and bridges over the waterway; but, if through unforeseen contingency these funds prove insufficient, the United States would be warranted in assisting the State by contributing such part of the cost as might be eventually found necessary to complete construction of suitable locks in the dams below Lockport and of bridges over this section of waterway.

As to minor differences or suggestions of the Board of Engineers for Rivers and Harbors, the following remarks are submitted: It was anticipated by the special Board that report on the improvement of the Mississippi River by dams at or near Jefferson Barracks and Commerce would be submitted before the next session of Congress and before the State of Illinois could take the action toward the construction of the waterway between Lockport and Utica, which is considered necessary to warrant the United States in adopting any project for the section of the Mississippi River in question. The recommendations of the special Board as to the diversion of water from Lake Michigan are that said diversion be restricted to the minimum required for purposes of sanitation; but should the diversion eventually authorized by Congress exceed that contemplated by the Board a change in the method of improvement of the Illinois River as indicated by the Board of Engineers for Rivers and Harbors may then be desirable. If the United States authorizes the Sanitary District of Chicago to divert water from Lake Michigan for purposes of sanitation, and also conveys to the State any equities it may possess in the rights of way or other properties of the Illinois and Michigan Canal upon completion of the proposed waterway as recommended by the special Board, it is believed that such action would relinquish to local agencies any rights the Government may have in the water power to be developed between Lockport and Utica. It was anticipated by the special Board that no action would be taken by Congress for the adoption of any definite project until the State of Illinois was in the position to guarantee the expenditure of $20,000,000 on the section of the waterway between Lockport and Utica, and that any such legislation by Congress would be made to harmonize with any policy that it might adopt with reference to the diversion of water from Lake Michigan under the recent treaty with Great Britain.

By the terms of the river and harbor act approved June 25, 1910, I am member and president of the special Board, and I concur in its report.

It is believed that the $1,000,000 already appropriated by the United States should be expended in improving the Illinois River below Utica to the depth recommended by the Board; but that this work should not be undertaken until an equal or greater depth above Utica is assured by the plans and operations of the State of Illinois.

Very respectfully,

W. H. Bixby,
Chief of Engineers, U. S. Army.

The Secretary of War.

REPORT BY A SPECIAL BOARD OF ENGINEERS ON WATERWAY FROM LOCKPORT, ILLINOIS, TO MOUTH OF ILLINOIS RIVER.

War Department,
Office of the Chief of Engineers,
Washington, January 23, 1911.

Sir: The Board of Engineers appointed by the Secretary of War September 8, 1910, in Special Orders, No. 43, Office of the Chief of Engineers, for the consideration of a waterway from Lockport, Ill., by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River, has the honor to submit the following report, supplemental to its preliminary report of November 1, 1910:

FEASIBILITY OF THE WATERWAY.

In the numerous surveys, under instructions from Congress, for a waterway from the Great Lakes to the Mississippi River, the line from Bridgeport, on the South Branch of the Chicago River, to Lockport, on the Des Plaines, thence along the Des Plaines River to the Illinois, and along the Illinois to its mouth, has uniformly been considered the most feasible. In all projects a canal has been proposed from Bridgeport to Lockport, and the river bed utilized below La Salle. In the earlier ones, a canal between Lockport and La Salle was advocated, but since the Chicago Drainage Canal has been excavated through the Chicago divide and now insures an adequate supply of water for the channel, the canalization of the Des Plaines and Illinois Rivers, with short canals around rapids, has been generally recommended. In the valley of the Des Plaines and upper Illinois rivers the rock is sufficiently near the surface to provide excellent foundations; the lower Illinois has an exceptionally gentle slope, averaging about 0.13 foot per mile, so that any reasonable depth can be obtained by dredging, and the present diversion from Lake Michigan through the Chicago Drainage Canal is more than sufficient for the channel. It is therefore the opinion of the board that the waterway from Lockport to the mouth of the Illinois River is feasible.

THE MOST ADVISABLE DEPTH AND DIMENSIONS FOR THE WATERWAY.

Waterways from the Great Lakes to the Mississippi River have been proposed varying in depth from 4½ to 24 feet. In determining the most advisable depth of the waterway it is necessary to consider the probable commerce, its character, its origin, its destination, and the dimensions of the vessels in which it can be most economically transported. Experience has shown that as a general rule coarse and bulky articles seek water transportation, while the finer manufactured products are shipped by rail. Of the 62,363,218 tons transported through the St. Marys Falls Canals in 1910, about 97 per cent consisted of iron ore, coal, grain, and lumber. Crude manufactured products, such as pig iron, ingots, and steel rails, are also naturally shipped by water, and in thickly settled communities like New York there is a large water commerce in building materials, such as brick, stone, lime, cement, sand, and gravel.

The Illinois River flows through one of the richest farming regions of the United States. There are along its banks large mineral deposits, especially coal, building stone, and the ingredients for making cement, so that the valley itself is capable of producing a large amount of the commodities which seek water transportation. The natural markets for this section are now Chicago and St. Louis, and were both New Orleans and the Northwest connected with the Illinois River by suitable water transportation they might become additional markets. The Board on a survey of the Mississippi River, whose report is published as House Document No. 50, Sixty-first Congress, first session, made a careful investigation of the probable commerce of the section of this water route from St. Louis, Mo., to its mouth, which is already of width and depth sufficient for its present commerce, and concluded that neither the natural and industrial resources nor the density of population along the Mississippi River were sufficient to create a large water-borne commerce, and that only from its tributaries could be expected a commerce sufficient to justify a large expenditure for greater dimensions. The Ohio River and its tributaries penetrate the iron and coal fields of the Appalachian system, and have on their banks large manufacturing centers at Pittsburg, Wheeling, Cincinnati, Louisville, Nashville, Chattanooga, and elsewhere. The upper Mississippi affords a line of water transportation for the grain, iron ore, and lumber of the Northwest, the Missouri reaches the grain fields of the West, and the White, Arkansas, and Red Rivers afford an outlet for southern products. In addition it is the expectation of many of the advocates of a waterway from Chicago to the Gulf that much of the commerce of the Great Lakes can be diverted thereto, although it now generally moves in an east and west direction. Finally, there is the commerce of the Gulf, expected to largely increase with the completion of the Panama Canal, some of which it is claimed would be carried to Chicago were an adequate waterway provided. There are, therefore, four sources of possible commerce for the proposed waterway: First, its immediate banks; second, the tributary rivers; third, the Great Lakes; and, fourth, the Gulf of Mexico.

The types of vessels which can most economically handle such commerce differ radically. A vessel navigating the ocean has to combat violent storms and severe wave action, and requires such relations between length, width, and depth as to secure good lines, great stiffness of hull, and maximum stability. For ocean service the experience of the past 50 years has evolved an economic freight steamer with a draft between 20 and 30 feet, though at a few of the principal ports vessels drawing from 30 to 40 feet are being introduced.

On the Great Lakes, since storm waves are not as large as on the ocean, and harbors of refuge are more frequent, less structural strength is necessary in vessels, and for the same draft the displacement may be much greater than on the ocean. Experience on the Great Lakes has evolved an economic bulk cargo steamer with a length of 550 to 600 feet, which, when loaded to an ultimate draft of 21 to 24 feet, carries a cargo of 10,000 to 15,000 tons. The package freighter employed on the Lakes by the various railway corporations is of somewhat smaller dimensions and has a draft of 18 to 19 feet. These two types of vessels now carry the bulk of the iron ore, coal, grain, and merchandise of the Great Lakes and the cost of transportation has been reduced at least half in the past 20 years.

On rivers, vessels are not exposed to wave action, and their structural strength and draft for the same displacement can therefore further be diminished. The early river packet was a frail stern or side wheel steamer having a draft of 3 to 10 feet, but as a freight carrier it has now been generally displaced by barges, which experience has demonstrated to be more economical. These barges have a draft not exceeding 8½ feet and a capacity up to 3,000 tons. They are assembled in tows and handled by a powerful towboat, in which the same economies in steam consumption are obtained as in the modern lake or ocean steamship.

The experience of foreign nations in river navigation is similar to that of the United States, as is illustrated by the enormous traffic of the River Rhine which, according to the "Statistik des Deutschen Reichs, Band 226," amounted in 1908 to about 54,000,000 tons between Strassburg and the Dutch frontier. The low-water depth of the channel upon which this large volume of freight was carried, as described in the preliminary report of the United States National Waterways Commission, 1910, was only 9.8 feet for 110 miles from the Dutch frontier up to Cologne, thence 8.2 feet for 82 miles to St. Goar, thence 6.6 feet for 79 miles to Mannheim, and thence 4 feet for 84 miles to Strassburg. About 30 per cent of the traffic of 1908 used the river above Cologne where the available depths vary, as above stated, from 4 feet in the section immediately below Strassburg, to a maximum of 8.2 feet in the section immediately above Cologne. Bulky commodities are transported in fleets of barges towed by special steamers designed for the purpose. The United States consul general at Berlin reported to the Department of State under date of August 18, 1909, that the capacity of the largest Rhine barges is over 2,600 tons, with a length of 336.6 feet, a beam of 39.6 feet, and a maximum draft of 9.4 feet; that the largest Rhine towboat has a length of 249.3 feet, a breadth of 29.5 feet, and that the most powerful have from 1,300 to 1,450 horsepower. Under date of March 7, 1910, he reported that the Rhine boats on an average are 237 feet long and 30.6 feet beam, with carrying capacity of from 480 to 1,000 tons on drafts of 4 to 7½ feet. Package freight is carried in separate steamers, and he stated that the capacity of the largest Rhine freight steamer is 975 tons, with a draft of 7.9 feet, a length of 278.9 feet, and a breadth of 29.5 feet. According to a report made by Maj. F. A. Mahan, Corps of Engineers, retired, in 1903 the total number of sailing vessels and towed barges on the Rhine was then 8,379, and the total number of towboats was 745, while of other steamers of all classes there were but 378, including 156 package freight steamers. According to information furnished by the American consul general at Frankfort in 1908 the Rhine fleet consisted of 1,318 steam vessels with indicated horsepower of 295,849 and 9,759 barges with a carrying capacity of 3,960,378 tons, or 11,077 vessels in all. These figures plainly show the predominating character of towboat navigation. No other river of Europe carries a commerce comparable with that of the Rhine, and it is clear that for the proposed waterway a channel equal to that now found on the Rhine will be adequate for an immense traffic.

From the preceding it follows that if the waterway is to be used by vessels capable of navigating the ocean and the Great Lakes, it should be given a depth sufficient for the economic carriers above described, and this, in the opinion of the Board, should be not less than 24 feet; but if it is to be constructed for vessels adapted to river traffic, economic navigation does not require its depth to exceed 9 feet. The depth of 14 feet, so strenuously insisted upon by certain advocates of the waterway, is greater than necessary for river navigation, and entirely insufficient for either lake or ocean vessels. The only canals of 14 feet depth of which the board has knowledge are the Canadian canals along the St. Lawrence River and the Welland Canal connecting Lakes Erie and Ontario, which were constructed in the infancy of lake navigation. Little use is now made of them for transportation to and from Chicago. This depth has not been adopted by any other nation, nor retained by Canada in recent projects.

A 24-foot waterway from Chicago to the Gulf has never been considered by Congress, but its cost would be enormous, and even if constructed, it would never be used commercially by the vessels for which designed. Barge navigation on rivers has been developed to such efficiency that it is estimated in House Document No. 492, Sixtieth Congress, first session, that coal can be shipped from Pittsburg to New Orleans in a 9-foot channel for 0.376 mills per ton-mile, which is a low rate even for lake and ocean vessels of 21-foot draft. Both lake and ocean vessels are designed for use in waters of great depth and unlimited width which they navigate with unrestricted speed and comparative safety, but on rivers, canals, or other contracted waters, they must materially reduce their speed and sometimes require assistance by tugs. In the report of the committee on the canals of New York State, 1899, it is shown that the first cost of lake vessels is so great, and their rate of speed on canals so slow, that interest charges alone will prevent them from competing with barge navigation. Moreover, on the Mississippi River, with its swift current, crooked channels, and other difficulties of navigation, insurance charges would place them at a further disadvantage as compared with the ordinary river craft. Ocean, lake, and river boats have been specially designed for the work they have to perform, and when diverted therefrom, lose in economy. Should a lake vessel drawing 14 feet attempt to engage in commerce between Duluth and Liverpool via the Mississippi River, it would be in competition with the modern lake freighter from Duluth to Chicago, the modern barge and towboat from Chicago to New Orleans, and the modern ocean freighter from New Orleans to Liverpool, each specially adapted to its portion of the route and able to carry freight for less than one-half the rate the vessel of 14 feet draft would be forced to charge.

Considered as a business investment, a waterway of even moderate depth from Chicago to the Gulf is still more or less experimental. There is already maintained under existing projects a channel of 9 feet depth from New Orleans to Cairo, and of 8 feet from Cairo to St.

Louis, and of at least 4½ feet from St. Louis to Chicago via the Illinois and Michigan Canal. With the exception of coal from the Ohio River, the existing commerce on any portion of this route is small. To justify even existing expenditures, commerce must be developed in the tributaries, and until it is created a further enlargement of the main stream will not be warranted. A uniform depth in the Mississippi and its leading tributaries will be far more beneficial to the navigation interests of the United States than a main channel of great depth with shallow feeders. As a channel of 8 feet depth is now maintained from Cairo to St. Louis, and can be extended from St. Louis to Utica at relatively small cost, business caution dictates that a waterway of this depth be obtained and tested before entering upon enormously expensive projects of questionable utility.

Should commerce respond to these comparatively moderate expenditures and utilize the waterway provided, and should an increasing traffic demonstrate the necessity for additional depth, then a channel of 9 feet depth can be constructed from Cairo to Utica. This can be obtained at a small additional cost and will correspond to the depth provided by the existing projects for improving the Ohio and lower Mississippi Rivers. For the locks and other new constructions between Utica and Lockport the extra foot of depth should be obtained at the outset, since its cost will be comparatively small. When a 9-foot waterway has been provided between Chicago, St. Louis, New Orleans, and the cities in the Ohio Valley, should navigation keep pace with the improvement and still greater depths appear economically desirable, they may be created without sacrificing the work now recommended by the Board. In such case, the original locks will still be valuable to provide for the smaller craft which will continue to navigate the minor tributaries as well as the main stream.

The course thus outlined corresponds to that which the Government has so successfully pursued with the large commerce on the Great Lakes, where it has deepened and enlarged channels as navigation has required. Harbors of 23 feet depth and the new 24½-foot lock at the St. Marys Falls Canal are now logical, but to have constructed them when the navigation of the lakes was confined to vessels drawing but 12 feet would not have been a judicious expenditure of public funds. The old Weitzel Lock is still profitably utilized for the passage of light-draft boats, and thus relieves the new deeper locks, which are frequently taxed to their full capacity.

The board considers a bottom width of 160 feet in canal and 200 feet in the open river above the mouth of the Illinois sufficient for a channel of 8 or 9 feet available depth. For safety and ease of navigation the channel should be excavated to 11 feet in rock cuts and canals, and the locks should be given 11 feet depth, 80 feet width, and 600 feet useful length. With these lock dimensions three barges, carrying about 9,000 tons of freight, may be locked through with their tow boat. A waterway of these dimensions would have a capacity exceeding 100,000,000 tons per annum, and would accommodate barge tows carrying about nine times the ordinary train load of this vicinity. In addition, the vessels using it would be capable of navigating the Ohio and lower Mississippi Rivers. Such a waterway will not require a diversion of more than 1,000 second-feet from Lake Michigan, and this amount would not injuriously lower lake levels nor cause excessive flooding of lands in the Illinois Valley.

COOPERATION WITH THE STATE OF ILLINOIS.

On December 8, 1910, the Hon. Charles S. Deneen, governor of Illinois, accompanied by Mr. Isham Randolph, chairman, and Mr. Robert I. Randolph, secretary, of the Internal Improvement Commission of Illinois, appeared before the board and made an explanation of the policy and plans of the State in connection with the development of the proposed waterway. In anticipation of the hearing, Mr. Isham Randolph, designated by the governor as the authorized agency of the State of Illinois, filed with the Board a letter and plans embodying the State's proposals. A copy of the letter accompanies this report, marked "Appendix A."

Briefly, the project presented by the State of Illinois contemplates the development of water power at 4 sites between Lockport and Utica, and the improvement of navigation by the construction of 5 large locks, 80 by 900 feet in horizontal dimensions, with 24 feet depth on their miter sills. The uppermost lock of the series will be at Lockport connecting with Lake Michigan, and the lowest will be at Utica, connecting with the already improved portion of the Illinois River. The locks between Lockport and Utica are to be connected by channels 300 feet wide, 24 feet deep as far as Lock No. 2 at Brandon Bridge below Joliet, and thence to Utica of not less than 9 feet immediate, and not less than 14 feet later, depth, and a bottom width of not less than 200 feet. These channels are to be in the river bed, except at the mouth of the Des Plaines River and at Marseilles, where short sections of canal are proposed. This project is practically the same as that printed in the 1909 report of the Internal Improvement Commission of Illinois, and the estimate of cost is $19,957,517. It differs from any heretofore submitted to Congress in that it proposes the utilization for power purposes of the water which may flow through the Chicago Drainage Canal and contemplates an ultimate channel depth of 24 feet for navigation purposes, though the estimates provide for 24 feet only to Brandon Bridge and for 14 feet below.

The Board of Engineers whose report on a survey for a navigable waterway 14 feet deep from Lockport to the mouth of the Illinois River is published in House Document No. 263, Fifty-ninth Congress, first session, estimates the cost of the same portion of the route at $15,647,902, but its plan contemplates 2 canals about 3 miles long at Joliet and Marseilles, and 5 movable dams and 9 locks. The locks are to be 600 by 80 feet, with 14 feet on the sills, and existing conditions are to be changed as little as practicable, thus avoiding damages to riparian owners whether for power rights or for overflow.

A careful examination has been made of the detailed estimates presented by the State of Illinois. So far as concerns the engineering features alone, such as excavation, construction of dams, locks, power plants, etc., the estimated cost is reasonable. The State's estimate, however, includes nothing for flowage damages nor for the purchase of water-power rights and franchises, and should the outcome of judicial proceedings now pending cause these damages and rights to assume great value, the State's estimate would then be insufficient.

For purposes of navigation a diversion from Lake Michigan of less than 1,000 second-feet of water is all that will be necessary. For purposes of sanitation the works of the Sanitary District of Chicago were designed to allow the diversion of 10,000 second-feet and now contemplate a total of 14,000 second-feet, the additional 4,000 second-feet to be obtained by the diversion of water through the Calumet River and a connecting canal following the Sag route. The War Department, while awaiting the definite action of Congress, has so far permitted the diversion of 4,167 second-feet and the Sanitary District is understood to be using about 7,000 second-feet. As the water which is at present being diverted from the lake appears to have already seriously affected the navigation of its harbors and connecting waterways, prompt congressional action is recommended to limit the diversion.

While it appears to have been assumed that the Sanitary District may be allowed to divert 10,000 second-feet so long as actually necessary for sanitary purposes, the diversion of the waters of the Great Lakes from their natural outlet for power development alone is inadmissible, under the recent treaty between the United States and Great Britain. The future diversion of water from Lake Michigan for any purpose is fraught with difficulties. Not only has Canada an interest in the maintenance of lake levels which the United States must recognize, but every foot of water flowing through the Chicago Drainage Canal lessens the flow at Niagara Falls and at the power sites along the St. Lawrence River, where, due to the fall available, the same amount of water will create about four times the power that can be generated from it on the Des Plaines and Illinois rivers. The treaty enables riparian owners of Canada, as well as of the United States, who consider themselves injured by such diversion, to bring suit in United States courts to protect their interests. The claim that more than 1,000 cubic feet per second is required for purposes of navigation can not be maintained. The treaty, however, recognizes as proper the use of water for sanitary purposes, and it is the opinion of the Board that only such water should be diverted from Lake Michigan as is indispensable for sanitation, and then only with a provision for proper compensating works in the outlets of the lakes to prevent a lowering of their levels. Water thus diverted may be used incidentally for power purposes, but care must be exercised in authorizing the diversion of water for sanitary purposes, to restrict it to the amount necessary for those purposes alone.

By virtue of the act of Congress of March 30, 1822, dedicating to the State of Illinois the land necessary for a canal connecting the Illinois River with Lake Michigan, and the act of March 2, 1827, granting to the State certain public lands for the purpose of aiding in its construction, and the acceptance by the State of the conditions imposed therein, the State of Illinois obligated itself to construct a suitable waterway from Lake Michigan to the navigable waters of the Illinois River. In accordance with this agreement the State constructed the Illinois and Michigan Canal, from Bridgeport to La Salle, and improved the upper portion of the Illinois River by the construction of locks and dams at Henry and Copperas Creek.

For many years this waterway was a valuable transportation route, but in recent years the State has neglected it and failed to maintain it abreast of the needs of commerce. The work now proposed by the State in connection with the canal of the Chicago Sanitary District contemplates a waterway from Lake Michigan to Utica, which, although departing from the line of the old canal, substitutes a waterway more than sufficient for any probable navigation. This will in effect fulfill the original agreement between the State and General Government for this section and incidentally develop a water power which the State considers a profitable business investment. State or local agencies are better adapted than the General Government for conserving water power for their citizens.

The Board believes that the State is more generous in its provisions for navigation than necessity requires, that the locks it proposes are larger than will be utilized, and that its original agreement would be amply fulfilled if it constructed locks 600 by 80 by 11 feet, and reserved at each lock ground sufficient for an additional lock should it ever be required, but it is also of the opinion that the State should be permitted to expend its own funds in such manner as it deems proper. With locks of the dimensions suggested by the Board the $20,000,000 authorized to be appropriated by the State should complete this part of the waterway; and unless large expenditures are required for power rights, even the larger locks could be constructed for that amount.

The General Government will then fully cooperate with the State in a waterway from Lockport to the mouth of the Illinois River if it assumes charge of the State structures at Henry and Copperas Creek, and enlarges the existing channel in the Illinois River below Utica to suitable dimensions. The Mississippi River from the mouth of the Illinois to St. Louis should also be suitably deepened.

CONDITIONS NECESSARY IN CONNECTION WITH COOPERATION TO FULLY PROTECT THE INTERESTS OF THE UNITED STATES.

A primary condition of any cooperation between the United States and the State of Illinois should be the acceptance in perpetuity of full responsibility by the State of Illinois or its agencies for all damages by changes in lake levels, including cost of compensating works, and for all damages to riparian owners, and the State should transfer to the United States the locks and the control of the new waterway thus created so far as needed by navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River. With such a transfer the obligations of the State of Illinois to the United States with reference to the maintenance of the Illinois and Michigan Canal may be considered as adequately fulfilled, and any equities of the United States in the rights-of-way and other properties of this canal should be transferred by the United States to the State of Illinois.

By this means the United States, at a relatively small outlay, can, with the assistance of the State of Illinois, make a test of the commercial value of an adequate inland waterway connecting Chicago with the cities of the Mississippi Valley. The plan of the State of Illinois to provide a navigable connection between the Great Lakes and the Mississippi River may be of such commercial value to the United States as to justify generous cooperation in its completion. The records of all previous investigations into the merits of such a waterway support this view. There is no objection to the State's giving the channel such dimensions as it may consider advisable in order to preserve the head of water for power purposes, provided they are not less than those considered necessary for navigation. Increased widths and depths will be incidentally of benefit to navigation by diminishing the velocity with which the water will flow in the channel.

Should the State of Illinois be unable to complete the locks suggested by the Board or the bridges required by navigation, the United States might then properly undertake to complete these parts of the project, but as the authorized appropriation of $20,000,000 by the State is considered sufficient for all work above Utica, no estimates are submitted for these parts.

PLANS AND ESTIMATES OF THE COST OF WORK RECOMMENDED TO BE DONE BY THE UNITED STATES.

The existing Federal project for the improvement of the Illinois River, adopted in 1880, together with the existing State project, provides for a 7-foot slackwater navigation from Utica to its mouth, which has been already obtained by dredging and by the construction of four dams, with locks 350 feet long, and 75 feet wide.

When this project was adopted the low-water discharge of the Illinois River was only about 500 cubic feet per second at Utica and about 1,000 cubic feet per second at its mouth. The opening of the Chicago Drainage Canal in 1900, however, radically affected the character of this stream, and has increased its low-water discharge at the present time to over 5,000 cubic feet per second, and raised the level of low water so that 8 feet can be carried to Grafton, provided that the upper miter sills at Henry and Copperas Creek are lowered about 1 foot, the crests of the dams are restored at the heights to which they were originally constructed, and portions of the pools deepened slightly by dredging.

While the present locks are smaller than the Board would recommend if new structures were to be created, they will efficiently provide for an extensive commerce, though large tows will have to be passed through them in sections. If a commerce should ever develop that would require the construction of larger locks, or a depth of 9 feet, the necessary locks can then be added.

Using the present locks, the estimate for an 8-foot waterway from Utica to the mouth of the river, is as follows:

Excavation in pools and in river below Kampsville	$887,545
Lowering miter sills and reconstructing gates	60,000
Restoring crest Kampsville Dam	7,000
Miscellaneous and contingencies, 10 per cent	95,455
Total	1,050,000

Including new locks the estimate for a 9-foot waterway, which may ultimately be required, is as follows:

Subdivisions.	Length in miles.	Excavation.	Locks.	Miscellaneous and contingencies.	Total.
Kampsville Lock to Grafton	31.5	$342,600	....	$34,260	$376,860
La Grange Lock to Kampsville Lock	46.0	338,600	$519,000	85,760	943,360
Copperas Creek Lock to La Grange Lock	59.3	259,409	505,000	76,441	840,850
Henry Lock to Copperas Creek Lock	59.3	310,500	480,000	79,050	869,550
Utica to Henry Lock	35.0	417,800	468,000	88,580	974,380
Total	231.1	1,668,909	1,972,000	364,091	4,005,000

The annual cost of maintenance below Utica is estimated as follows:

For an 8-foot waterway:	
4 locks, at $10,000	$40,000
Dredging	25,000
	65,000
For a 9-foot waterway:	
4 pairs locks, at $14,000	56,000
Dredging	35,000
	91,000
Above Utica: 5 locks, at $10,000	50,000

The report of the Board of 1905 for obtaining a 14-foot waterway (H. Doc. No. 263, 59th Cong., 1st sess.) provides for a movable dam at Alton, and a canal on the east side of the river between Alton and St. Louis, considered necessary for such depth on account of the steep slope in the Mississippi River in the vicinity of the Chain of Rocks between St. Louis and the mouth of the Missouri River, the large amount of sediment in the Missouri River, and the extreme variation in the regimen of the river at this locality.

For an 8-foot channel the main river can be utilized and the depths obtained by contraction works and shore protection as on the upper Mississippi and below St. Louis more cheaply than by a lateral canal. This will also allow to Missouri River boats free access both to the upper Mississippi River and to the portion of the river between St. Louis and the mouth of the Missouri River, which would be cut off by the Alton Dam. To obtain an 8-foot depth, it is proposed to contract the river to widths varying from 1,250 to 2,100 feet by a system of wing dams, to revet the caving banks, and to excavate through the Chain of Rocks a channel 500 feet wide and 10 feet deep at low water. The estimated cost of this work is as follows:

St. Louis, Mo., to Grafton, Ill.

Wing dams:		
Grafton to Missouri River, linear feet 60,400, at $12.50		$755,000
Missouri River to St. Louis, linear feet 26,500, at $25		662,500
Total for new wing dams		1,417,500
Repairs to old work		150,000
Shore protection:		
Grafton to Missouri River, linear feet 64,000, at $8	$512,000	
Missouri River to St. Louis, linear feet 54,000, at $15	810,000	
Total for shore protection		1,322,000
Rock excavation at Chain of Rocks, cubic yards 138,000, at $3.50		483,000
		3,372,500
Miscellaneous and contingencies, approximately 10 per cent		337,500
Total		3,710,000

The cost of annual maintenance is estimated at $125,000, including channel dredging.

A channel of 9 feet depth can subsequently be obtained by dredging, at an estimated additional cost of $75,000 per year.

When the existing project for an 8-foot waterway from St. Louis to Cairo is completed, it can be maintained at 9 feet by dredging for an additional expenditure of $100,000 annually.

The work recommended by the Board in the near future, therefore, consists of enlarging the channel of the Illinois River from Utica to its mouth to 8 feet, at an estimated cost of $1,050,000, and providing an 8-foot channel in the Mississippi River from the mouth of the Illinois to St. Louis, at an estimated cost of $3,710,000.

Until it obtains further data the Board defers its report upon the measures required to properly preserve the levels of the Great Lakes and to compensate so far as practicable for the diminished level in such lakes by reason of any diversion of water from Lake Michigan; upon the influence on volume and height of waters in the Mississippi River below Cairo; upon the effect upon the climate of the Lake States by a change in the natural currents of Lake Michigan; upon the improvement of the Mississippi between the mouth of the Illinois River and the mouth of the Ohio River by the construction of a dam at or near Jefferson Barracks, and a dam at or near Commerce, and the development of water power incidentally created by such dams.

Respectfully submitted.

W. H. BIXBY,
Brig. Gen., Chief of Engineers, United States Army.
C. McD. TOWNSEND,
Colonel, Corps of Engineers.
C. KELLER,
Major, Corps of Engineers,
J. B. CAVANAUGH,
Major, Corps of Engineers.
JOHN BOGART,
Civil Engineer.

The CHIEF OF ENGINEERS, U. S. ARMY.

[Second indorsement.]

THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, January 30, 1911.

Respectfully returned to the Chief of Engineers, U. S. Army.

This is the second report of the special Board of Engineers authorized by the river and harbor act of June 25, 1910, to consider the "waterway from Lockport, Ill., by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River." The preliminary report of November 1, 1910, merely outlined the subjects to be considered and explained the necessity of taking further time to report upon the matters specified by Congress in the act aforesaid. The present report covers five of these subjects, as follows:

(*a*) Feasibility of the waterway.

(*b*) The most advisable depth and dimensions for the waterway.

(*c*) Cooperation with the State of Illinois.

(*d*) Conditions necessary in connection with cooperation to fully protect the interests of the United States.

(*e*) Plans and estimates of the cost of work recommended to be done by the United States.

The special Board concludes:

(*a*) That the waterway is feasible.

(*b*) That 8 feet is the most advisable depth for immediate construction, to be increased later to 9 feet if the interests of commerce appear to require it, providing originally, however, 11 feet in rock cuts and canals and any new locks to be built, and giving a bottom channel width of 160 feet in canal and 200 feet in the open river above the mouth of the Illinois.

(*c*) That the United States should cooperate with the State of Illinois in a waterway from Lockport to the mouth of the Illinois River, the State building that portion from Lockport to Utica, and the United States providing that portion between Utica and the mouth of the Illinois River, assuming charge of the State locks and dams at Henry and Copperas Creek, and also the maintenance and operation of the locks to be provided by the State between Lockport and Utica.

(*d*) That "a primary condition of any cooperation between the United States and the State of Illinois should be the acceptance in perpetuity of full responsibility by the State of Illinois or its agencies for all damages by changes in lake levels, including cost of compensating works, and for all damages to riparian owners, and the State should transfer to the United States the locks and the control of the new waterway thus created so far as needed by navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River."

(*e*) That the work now recommended to be done by the United States, using the present locks (75 by 350 feet) and providing an 8-foot waterway, will involve excavation in the pools and open river, lowering miter sills, and reconstructing gates, and restoring the crest of the Kampsville Dam, at a total estimated cost of $1,050,000. The estimate for the 9-foot waterway and new locks (80 by 600) that may ultimately be required is $4,005,000. The annual cost of maintenance is estimated at $115,000 for the 8-foot waterway, and $141,000 for the 9-foot waterway.

The special Board also submits a plan and recommendation for open-river improvement in the Mississippi River to provide a depth of 8 feet between the mouth of the Illinois River and St. Louis, at an estimated cost of $3,710,000, with an annual charge of $125,000 for maintenance. It states that after the 8-foot channel is provided, a depth of 9 feet can be obtained by dredging between these points with an additional annual expenditure of $75,000. It thus appears that the estimated annual cost of maintenance to be assumed by the United States is $240,000 for the proposed 8-foot waterway from Chicago to St. Louis and $341,000 for the 9-foot waterway.

Pending the collection of further data, the special Board does not report upon the improvement of this portion of the Mississippi River by dams at or near Jefferson Barracks and Commerce, and upon the other matters specified in the law, viz, the measures required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in such lakes by reason of any diversion of water from Lake Michigan, the influence of volume and height of waters in the Mississippi River below Cairo, and the effect upon the climate of the Lake States by a change in the natural currents of Lake Michigan.

After careful consideration, the Board of Engineers for Rivers and Harbors concurs in general with the special Board in its conclusions concerning the waterway from Lockport, Ill., to the mouth of the Illinois River, but it does not believe that the plan of improvement proposed for the Mississippi River between the mouth of the Illinois and St. Louis should be adopted until report has been made as required by Congress upon the improvement of the Mississippi River by dams at or near Jefferson Barracks and Commerce.

It does not concur with the view of the special Board that the United States should assume that part, if any, of the cost that is in excess of $20,000,000 for constructing the portion of the waterway between Lockport and Utica. Moreover, it suggests that the amount of diversion to be permitted from Lake Michigan should be determined, if practicable, before the project is undertaken. Not only may this affect the attitude of the State toward the work, but also when the approximate minimum flow is known it may be found advisable to substitute open channel work for the four existing locks and dams that are retained in the plan of the special Board.

It is understood that the Sanitary District of Chicago and the State expect to develop considerable water power on that portion of the waterway between Chicago and Utica. As it is proposed that the navigable channel between these points shall be built without cost to the United States, it is believed that the General Government should relinquish to these local agencies any rights that it may have in the power to be thus developed. It does not appear that there is any question of water power, flood control, or other matter that can be coordinated with that portion of the work to be done by the United States for the improvement of navigation, so as to lessen the cost and compensate the Government for its expenditures made in the interest of navigation.

In conclusion it is recommended that the work proposed by the special Board for the United States in the Illinois River be not undertaken until the Secretary of War has received satisfactory assurance from the State of Illinois that the State will build that portion of the waterway from Lockport to Utica without cost to the United States, and in accordance with plans to be approved by him; and, further, until the interests of the United States have been satisfactorily safeguarded as indicated by the special board, viz, that the State of Illinois or its agencies shall assume entire responsibility in perpetuity for all damages by changes in lake levels incident to the work, including cost of compensating works, and for all damages to riparian owners along the proposed waterway from Lake Michigan to the mouth of the Illinois River, and that the State shall transfer to the United States the locks and the control of the new waterway thus created so far as needed for navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River.

Complying with the requirement in section 3 of the river and harbor act of June 25, 1910, that "reports containing plans and estimates shall also contain a statement as to the rate at which the work should be prosecuted," the Board reports that as the appropriation of $1,000,000, in accordance with which the present investigation is made, is approximately equal to the estimated cost of the work proposed, it appears that no further appropriation is now needed and that the work may be prosecuted at the maximum rate consistent with its economical execution after the adoption of the project by Congress and the assumption of the obligation recommended to be imposed upon the State of Illinois.

For the Board:

Wm. T. Rossell,
Colonel, Corps of Engineers,
Senior Member of the Board.

LETTER OF MR. ISHAM RANDOLPH, THE AUTHORIZED AGENCY OF STATE OF ILLINOIS.

CHICAGO, *November 5, 1910.*

DEAR GENERAL: I am sending you the communication addressed to the Board of which you are chairman, together with other data desired by yourself and associates. Gov. Deneen approves of the policy outlined in my communication to your commission and accepts it without omission, addition, or amendment of any kind and we will put the questions at issue up to the State legislature just as we present them to you.

The governor will be pleased to confer with your commission in Washington on or about the 8th of December.

Yours, cordially,

ISHAM RANDOLPH.

Gen. WILLIAM H. BIXBY,
Chief of Engineers, Washington, D. C.

LETTER OF REPRESENTATIVE OF STATE OF ILLINOIS.

CHICAGO, *October 26, 1910.*

GENTLEMEN: Having been delegated by the governor of Illinois, Hon. Charles S. Deneen, to represent said State as "the authorized agency" to confer with you in the effort to reach a basis upon which "the United States may properly cooperate with the State of Illinois in securing a navigable waterway from Lockport to the mouth of the Illinois River, in conjunction with the development of waterpower by said State between Lockport and Utica * * * "; I have the honor to submit for your consideration certain facts and arguments based thereon which I trust will bring about the cordial cooperation between the Nation and the State, which means so much to our whole people.

On the 3d of November, 1908, the people of the State of Illinois had submitted to them by joint resolution of the senate and house convened as the forty-fifth general assembly a proposition to amend the constitution in such manner as to permit the State to issue $20,000,000 in bonds, the proceeds of which should be used "for the construction of a deep waterway or canal from the present water power plant of the Drainage District of Chicago at or near Lockport, in the township of Lockport, in the county of Will, to a point in the Illinois River at or near Utica, which may be practical for a general plan and scheme of deep waterway along a route which may be deemed most advantageous for such plants, locks, bridges, dams, and appliances sufficient and suitable for the development and utilization of the water power thereof," etc. The amendment was carried by the largest majority ever given to any measure presented to the people of Illinois, 675,898 ayes, 193,298 nays, 284,871 not voting on this issue. There has been no later consideration of this amendment and the overwhelming vote of the people remains of record in its favor.

The execution of the will of the people came in regular order of business before the forty-sixth general assembly. By request of the governor, a waterway bill was prepared by the Internal Improvement Commission of Illinois, designed to meet the requirements outlined in the joint resolution already quoted. This draft was submitted to Mr. John P. Wilson, an able constitutional lawyer of national reputation, who revised it so that it would be a strictly legal enactment. It was then given to the governor, who intrusted it to the late Senator Frank D. Schmitt for presentation to the Senate, where it became bill No. 52.

It was introduced on January 28, 1909, given a first reading, ordered printed, and referred to the committee on waterways. In that committee it underwent further revision, and on April 29, 1909, was voted out as senate bill 465, and without further amendment it passed the senate. It was defeated in the house.

At the special session of the forty-sixth general assembly this bill—known as the Schmitt bill—was again passed by the senate as bill No. 18 and was again defeated in the house. You have been supplied with copies of said bill No. 18 as printed, and with a section added by me to meet the requirements of the cooperation with the United States desired between Lockport and Utica. This section, which would be No. 18, reads, "When the channel shall have been completed in conformity with the provisions of sections No. 1 and No. 5 hereof, or so much of said channel shall have been built as can be paid for with the proceeds of the $20,000,000 of bonds authorized to be sold under the provisions of section 13 hereof, then the said channel, or so much thereof as shall have been completed, shall be tendered to the Government of the United States for navigable uses, conditioned upon the obligation of said Government to maintain the channel for navigation and to operate and maintain the locks free of cost to the State of Illinois. For all uses other than navigation, the channel and its appurtenances shall be and forever remain the property of the State of Illinois."

I will not in this communication present any argument in support of the proposition that the Government will not have discharged its duty to the people of the United States until it has provided a waterway from the Great Lakes to the Gulf of Mexico, but will for my present purpose assume that as an admitted contention. I have submitted to you the report of the Internal Improvement Commission of Illinois covering a project presented by it for the waterway from Lockport to Utica. By reason of its official relation to this whole subject that commission availed itself of the data secured by the several boards of United States engineers who have made surveys and reports, called for by sundry acts of Congress, covering the waterway from Lockport to Utica. Of these surveys and reports the most exhaustive was that of 1905. Under caption "The State project" this proposed construction is described and the estimated cost of creating it is given on pages 46 to 53 of that report, and maps showing the route and the location of locks and dams are bound up in the report. These estimates have received the critical attention of a prominent member of the profession, and I have submitted to you his criticisms and my reply thereto. Should you desire them, I will submit the estimates in detail, which were prepared under my direction.

I do not, as the conferee for the State nor as chairman of the Internal Improvement Commission, ask you to adopt or approve that plan, which, should further study and more detailed investigation of physical conditions suggest alterations, we are prepared to revise and improve upon. What I ask on behalf of the State is that you recommend to the United States that it accept from the State of Illinois a channel, or so much thereof as can be built with the proceeds of the sale of $20,000,000 of State bonds, provided the work done shall be of a substantial and permanent character, and that the channel shall be of such ample dimensions as to carry the full volume of water which may flow through it at velocities entirely consistent with safe and easy navigation by all water craft—of such length, breadth of beam, and depth of draft as can pass through the locks—which may seek passage through said channel. And further, that should the $20,000,000 to be provided by the State prove insufficient to complete the work in its entirety, the United States defray the cost of completion upon plans approved by its Chief of Engineers and carried out under the direction and control of the War Department.

The manifest intent of bill No. 18 is that the State of Illinois shall be the owner of the water power which will be created as outlined in that bill. In the 1905 report upon the 14-foot waterway made "by a board of officers of the Corps of Engineers, United States Army," on page 12 occurs this language: "The best development of water power would no doubt in some cases call for a different arrangement. Fewer dams and those of greater height and of a fixed type might from that point of view be desirable. The plan submitted is not designed to develop water power; but there will probably be no difficulty in modifying it so as to conform to such development if those to benefit thereby will cooperate with the Government. They should pay the cost of the dams and the damages from flowage, which is no more than they would be compelled to do if the Government made no improvement."

The State of Illinois seeks to comply with the principles laid down by that "board of officers of the Corps of Engineers of the United States Army," and to do more than they recommend, for it seeks to build a waterway of greater dimensions than those called for by the recommendations of the said officers, and not only to build the channel and the dams but to build the locks, or so many of them as the money to be made available under the constitutional amendment authorized by the franchised people of the State on November 3, 1908, can pay for, after paying for the channel, the dams, and the water power; and in return it asks that the water be allowed to flow and that it, the State, may become the beneficiary of the water power made possible by that flow and made available by the work of the State and paid for with its money. The uses of water abstracted from Lake Michigan are of merit in the order named: Sanitation, navigation, water power.

So far as I—your conferee—am consulted or can influence the action of the State of Illinois, that advice will be given and that influence exerted to bring about a speedy prosecution of the work upon the following basis: That all rockwork shall be given its full width and depth; that the northernmost lock at the Sanitary District power house be built; that the dams and power houses be built; that the plans south of Joliet shall provide for a channel, the ultimate depth of which shall not be less than 14 feet and the immediate depth of which shall not be less than 9 feet; that the locks shall be built so far as they can be with the money provided by the State; and that should that money not suffice to build all of the locks, that the sites of the locks which can not be built with the State funds be carefully preserved and the adjacent dams be so constructed as that they can be easily and properly joined to the locks. In all cases care will be taken to so locate the power houses and forebays that they may not be an obstruction or hindrance to navigation.

Respectfully submitted.

ISHAM RANDOLPH,
Conferee for the State of Illinois.

Commissioners appointed by the Secretary of War under certain requirements of H. R. 20686 (see Pub. Doc. No. 264):

Gen. W. H. BIXBY, *Chairman.*
Col. C. McD. TOWNSEND.
Maj. J. B. CAVANAUGH.
Maj. C. KELLER.
Mr. JOHN BOGART.

BILL INTRODUCED IN THE GENERAL ASSEMBLY OF THE STATE OF ILLINOIS TO AUTHORIZE THE CONSTRUCTION OF A WATERWAY FROM LOCKPORT TO UTICA, ILL., BY THE STATE OF ILLINOIS.

[Senate, No. 18, Forty-sixth Assembly, Special Session, December 14, 1909. Resubmitted to Illinois State Legislature, December, 1910.]

Introduced by Mr. Schmitt, December 14, 1909.—Read first time, ordered printed and referred to Committee on Waterways.

A BILL For an act to provide for the construction of a deep waterway, or canal, from the water power plant of the Sanitary District of Chicago, at or near Lockport, to a point in the Illinois River, at or near Utica, and for the development and utilization of the water power that may be created from the water flowing through said waterway, and to create a commission to carry out the provisions of this act.

SECTION 1. *Be it enacted by the people of the State of Illinois represented in the general assembly:* That a deep waterway, or canal, be constructed by the State of Illinois from the water power plant of the Sanitary District of Chicago, at or near Lockport, in the township of Lockport, county of Will, to a point in the Illinois River at or near Utica, and that there shall also be erected, equipped, and maintained by the State of Illinois, power plants, locks, bridges, dams, and appliances sufficient and suitable for the development and utilization of the water power of said deep waterway, or canal, and that the cost of constructing, erecting, and equipping the aforesaid public works shall be paid out of the proceeds of bonds of the State of Illinois to be issued and sold as hereinafter provided.

SEC. 2. The construction, management, and operation of said deep waterway, or canal, power plant, locks, bridges, dams, and appliances, shall be under the control of a board of five (5) commissioners to be known as the Board of Commissioners of the Illinois Deep Waterway; not more than three (3) of which said commissioners shall belong to or be affiliated with the same political party. The said commissioners shall be appointed by the governor, by and with the consent of the senate. The governor shall designate one of said commissioners to be the chairman of said board. Of the commissioners first appointed two (2) shall hold office until the 1st day of July in the year 1911, two (2) shall hold office until the 1st day of July in the year 1913, and one (1) shall hold office until the 1st day of July in the year 1915. The successors in office of the commissioners first appointed, as aforesaid, shall also be appointed by the governor, by and with the consent of the senate, and each successor in office thus appointed shall hold office for a term of six (6) years from the date of the expiration of his predecessor's term of office; except that members who shall be appointed to fill vacancies occurring otherwise than by lapse of time shall hold office only for the unexpired term of the member in whose place the new member shall be appointed. The said board shall adopt an official seal and may authenticate all its official acts with the same. For all legal purposes the said commissioners shall be deemed officers of the State, and all business, contracts, writings, and acts shall be made and suits prosecuted by them in the name of the Board of Commissioners of the Illinois Deep Waterway; but they shall not be considered a distinct corporation. Before entering upon the duties of his office each commissioner shall take and subscribe the following oath:

"I do solemnly swear (or affirm, as the case may be) that I will support the Constitution of the United States and the constitution of the State of Illinois and that I will faithfully discharge the duties of the office of deep waterway commissioner according to the best of my ability."

He shall also give an official bond, payable to the people of the State of Illinois, in he sum of twenty-five thousand dollars ($25,000) with at least two (2) sufficient sureies, to be approved by the governor, conditioned for the faithful discharge of his ffice and for a faithful accounting of all moneys entrusted to him as such commisioner, whenever and as often as he shall be lawfully required. Such oath and bond hall be filed in the office of the Secretary of State.

Sec. 3. The said board shall appoint a secretary, a treasurer, a chief engineer, and n attorney, and such other officers, agents, and assistants as said board may deem ecessary. The chairman of the board shall be the presiding officer at all meetings of he board and shall hold his office for two years and until his successor is appointed, nd shall be the executive officer of said board and shall sign all official documents manating from or authorized by said board. All officers elected by said board shall old their respective offices during the pleasure of the board; and said board shall precribe the duties and fix the compensation of all the officers, agents, and employes of aid board.

Said board shall have power to pass all ordinances, rules, and regulations which may, n the opinion of said board, be necessary for the proper management and conduct of ts business and to accomplish the objects for which it is created. All business of said oard shall be transacted at regular meetings of the board or at meetings held in accordnce with its rules. The affirmative vote of at least three (3) members of said board hall in all cases be necessary to transact business and to authorize the making of any ontract or appropriation or expenditure of money.

Sec. 4. Each of the aforesaid commissioners shall receive a salary of five thousand ollars ($5,000) per year, while that one of the said commissioners who shall be desigated as chairman of the board shall, in addition to his annual salary of five thousand ollars ($5,000) as commissioner, receive the further sum of two thousand five hundred ollars ($2,500) per year, making his salary seven thousand five hundred dollars ($7,500) per year so long as he shall be the chairman of said board.

The attorney for said board shall receive a salary of not to exceed five thousand ollars ($5,000) per year.

Sec. 5. The secretary shall be the custodian of the records of said board and shall enter upon permanent records the official minutes of all meetings of said board, in which shall be entered all the official acts of said board and a record of the votes of the several members of the board upon all ordinances or resolutions authorizing the making of contracts or the expenditure or appropriation of moneys.

The said board before entering into any contract for the construction of any part of said deep waterway, or canal, or any other of the said public works connected therewith, shall cause to be made plans and specifications for the said public works, together with reliable and carefully prepared estimates of the cost of constructing, completing, and installing all of said public works, for the purpose of ascertaining whether the total cost of the construction, completion, and installation of said public works can with certainty be defrayed with the proceeds of the twenty million dollars ($20,000,000) of said bonds authorized to be issued by the amendment to the constitution of the State of Illinois, adopted by the vote of the people in the year 1908. And if, upon the completion of said plans and specifications and the estimates based thereon, it becomes evident to the said board that the said sum of twenty million dollars ($20,000,000) is not sufficient to defray the cost of the entire work, but is sufficient to build and construct the aforesaid waterway and all of the aforesaid public works except the locks, they shall proceed to build the same, and if there is shown to be money in excess of the cost of the works thus undertaken, then the money in excess of that cost shall be expended in building the locks or so many of them as can be paid for by the funds provided. The first lock to be constructed shall be the most northerly one of the series required for the waterway, and such additional locks as can be built with the money shall be constructed in consecutive order along the downward course of the said waterway or canal. And no changes shall thereafter be made in the said plans and specifications which, in the opinion of said board, would have the effect of increasing the aggregate cost to the State of said public works to an amount in excess of twenty million dollars ($20,000,000), unless the State shall, by due process of law, authorize additional expenditures.

Subject to the limitations above specified the said board is hereby authorized, empowered, and directed to do and to cause to be done all things necessary for the construction, erection, equipment, and installation of the said deep waterway or canal, power plants, locks, bridges, dams, and appliances.

The route adopted for said waterway or canal shall be through and along the Sanitary District Channel from the power plant at Lockport to Joliet, thence in, along or near the Desplaines and Illinois Rivers to its terminus, a point in the Illinois River at or near Utica. Said deep waterway or canal shall have a depth of not less than twenty-four (24) feet from the power plant at Lockport to Brandon's Bridge, below Joliet, and a width of not less than three hundred (300) feet from the confluence of the Desplaines River with the pool known as the Upper Basin, in Joliet, to Brandon's Bridge, below Joliet, and from that point to its terminus, at or near Utica, shall have an ultimate depth of not less than fourteen (14) feet and a bottom width of not less than two hundred (200) feet. All permanent structures appertaining to said waterway, or canal, shall be built with a view to an ultimate depth of 24 feet throughout the entire length of said waterway or canal.

Sec. 6. The elevation of the water level within the confines of the city of Joliet shall not be higher than forty-two (42) feet below Chicago datum, and to provide for the maintenance of said level, suitable waste gates and regulating devices shall be installed to insure an elevation of water not higher than aforesaid in times of extreme flood.

Sec. 7. Special provision shall be made where the channel passes through cities, towns, and municipalities to adequately care for the drainage, sewerage, and flood waters discharged from the drainage areas involved by constructing intercepting sewers and diverting water courses to lower levels.

Sec. 8. Modern bridges of adequate size and suitable design, including all necessary piers, abutments, substructures, superstructures, and approaches, shall be constructed across the full width of the channel, to replace present existing structures owned by municipalities, townships, and counties. One-fourth of the cost of maintaining these bridges shall be borne by the municipality, township, or county, and three-fourths of such cost shall be borne by the State. All damages to property, including the expense of constructing and paving approaches, retaining walls, and sidewalks, rendered necessary by the raising and lengthening of bridge spans, as aforesaid, shall be adjudicated by the court of claims and be paid out of the funds under the control of the said board of commissioners. To provide the necessary facilities for crossing the proposed navigable channel with water mains, fire and police telegraph wires and all public utilities, owned by municipalities, now using existing bridges, there shall be constructed at such bridges adequate and suitable tunnels or conduits below the bed of the river channel for such purposes.

Sec. 9. When it shall be necessary, in the opinion of said board, for the economical and successful construction, operation, and maintenance of the said deep waterway and other public works hereinbefore specified, to enter upon and use any public property or property held for public use, said board shall have the power to do so, and enter upon, occupy, use, widen, deepen, and improve any waterway, canal, pool, or lake, but the public use thereof shall not be unnecessarily interfered with. The property which the said board is authorized to enter upon and use under this section includes all property and all interests in property which the State of Illinois has the lawful power to appropriate to the uses of said waterway or other public works without making compensation therefor.

Sec. 10. Whenever the said board shall pass an ordinance or resolution for the construction of any part of the said deep waterway, or canal, or other public work or adjunct thereto, the making of which will require that private property should be taken or damaged, such board may cause compensation therefor to be ascertained and paid and acquire possession thereof in the same manner, as nearly as may be, as is provided for in an act entitled "An act to provide for the exercise of the right of eminent domain," approved April 10, 1872, and the amendments thereto: *Provided*, That the proceedings to ascertain such compensation shall in all cases be instituted in the county where the property sought to be taken or damaged is situated. The property which the said board is authorized to acquire under this section shall include all property and all interests in property which the State of Illinois has not the lawful power to appropriate to the uses of said waterway and other public works without making compensation therefor.

Sec. 11. Subject to the limitations contained in this act, the said board is hereby authorized to acquire by purchase all property, real and personal, which, in the opinion of said board, are neceessary or desirable for the construction, equipment, and maintenance of the public works hereinbefore specified and committed to the care of said board, to appoint and employ all officers, assistants, agents, and employes, to enter into all contracts and to do all other acts which, in the opinion of said board, may be necessary or desirable for the construction of said deep waterway and for the erection, equipment, and maintenance of said power plants, locks, bridges, dams, and appliances, and the necessary adjuncts thereto.

All contracts for work to be done and material required by said board under authority of this act, the expense of which will exceed one thousand dollars ($1,000), shall be let to the lowest responsible bidder therefor, upon not less than sixty (60) days' public notice, the terms and conditions upon which such contracts are to be let to be given by publication in a newspaper of general circulation in the State of Illinois and also in an engineering paper having general circulation in the United States. And said board shall have power and authority to reject any and all bids and readvertise: *Provided, however*, That said board may cause any piece of work to be performed by the direct mployment of labor without the letting of a contract, which, in the discretion of the oard, evidenced by the affirmative vote of not less than four (4) of the commissioners, an be most economically performed by that method. And all labor so employed hall be under the direction of the chief engineer and his properly authorized assistnts: *And provided further*, That machinery may be purchased upon a like vote, ithout soliciting competitive bids.

The said board is hereby directed, in letting contracts for the construction of the foresaid public works, to require of all contractors, as a condition precedent to the cceptance of their bids, that they shall, according to a scale of benefits to be fixed by aid board, adequately insure all workmen employed by them or by their subcontractors gainst risk of injury or death suffered in the course of their employment, the requirenents thus imposed upon contractors to be uniform, as nearly as may be, in all cases.

And in case the State shall undertake the construction of said public works, or any art thereof, by the direct employment of labor, any employee of the State injured n the course of his employment without wilful misconduct on his part, or in case of is death in consequence of such injury, his dependents, shall be relieved and comensated out of the funds under the control of said board in accordance with such eneral regulations as it may establish and is hereby directed to establish for that urpose.

Sec. 12. The said board is hereby vested with all police powers necessary to preerve the peace and protect property and preserve health within the territory coniguous to said deep waterway, within a distance of two (2) miles on either side thereof, ut excluding therefrom all territory within which any incorporated city, town, or illage is vested by law with the same police powers which are hereby granted to aid board. For the enforcement of said police power, the said board is authorized o organize a police force, the members of which shall have all the powers vested y law in constables. The said board shall also have power to prescribe sanitary egulations for all camps, boarding houses, dwellings where the employees of said oard are domiciled, and any violation of any police or health rule or regulation of said oard shall be deemed a misdemeanor punishable as such upon trial and conviction s provided by law in other cases. Said board shall have power to appoint a health fficer, who shall be a physician, and to prescribe his powers and duties.

Sec. 13. For the purpose of defraying all expenditures of said board made by uthority of this act there shall be issued and sold, in the manner and at the times ereinafter recited, bonds of the State of Illinois to an amount not exceeding twenty nillion dollars ($20,000,000) and the proceeds thereof shall be paid to the State treasrer, who shall keep an account of the same as a separate fund to be known as the "Waterway fund" and to be drawn upon by the said board in the construction and naintenance of the aforesaid public works. The board of commissioners is charged vith the duty of selling said bonds to the highest bidder after advertising for a period f sixty (60) consecutive days, Sundays excepted, in at least two daily newspapers, ne of which shall be printed in the city of Springfield and the other in the city of hicago. The said board may reject any and all bids made in pursuance of said dvertisements, and in such event is authorized to re-advertise for bids in the manner bove described as many times as may be necessary to effect a satisfactory sale. One-ifth of each issue of said bonds shall be in denominations of two hundred dollars ($200) ach, one-fifth in denominations of five hundred dollars ($500) each, and three-fifths in enominations of one thousand dollars ($1,000) each; and in the sale of said bonds, as ereinafter provided, the board of commissioners shall, in the case of intending purhasers who bid the same price, give the preference to those who bid for the smaller quanity. Said bonds shall not all be issued and sold at one time, but shall be issued and sold rom time to time, as the work proceeds, in amounts necessary to meet the obligations ncurred by said board as they shall be estimated by the chief engineer and reported o and approved by said board. All bonds issued shall be dated as of the first day of anuary or the first day of July next preceding the date of their issue, and shall draw nterest, payable semi-annually, evidenced by interest coupons, at a rate not exceedng four (4) per cent per annum, and shall be sold for not less than par. All bonds ssued shall be made payable in twenty (20) years from the date of their issue, and, n the discretion of the said board, may be made redeemable in ten (10) years from the ate of their issue. They shall be engraved and printed under the direction of the overnor, shall be under the seal of the State, shall be signed by the governor, and ountersigned by the treasurer and auditor of the State, and until sold shall be eposited with the State treasurer. The estimate made and approved, as aforeaid, of the funds which will be required to meet the obligations for the said work, ncluding maturing interest on outstanding bonds for a period of six (6) months begining with the 1st day of January or July next ensuing thereafter, shall be made and iled with the Governor of the State of Illinois in the months of April and October f each year.

SEC. 14. All payments for salaries, wages, work done under contract, materials, supplies, machinery, lands and damages to lands, shall be made by the State treasurer out of the aforesaid waterway fund, upon warrants drawn by the auditor of public accounts, based upon bills of particulars and vouchers certified by the official or agent of the said board having knowledge of the facts upon which the said vouchers are based, audited by the secretary and approved by the chairman of the board. The said board shall prescribe the manner in which payment shall be made for the current and emergency expenses and provide for safeguarding all disbursements of funds on this behalf. The said board shall have power to keep under its control a fund to meet immediate demands and expenses, not exceeding at any one time fifty thousand dollars ($50,000.00), and for the purpose of creating the said emergency fund the auditor of public accounts is authorized in the first instance to issue his warrant for the sum of fifty thousand dollars ($50,000.00) at the direction of the said board, and payable to its treasurer; and the auditor of public accounts is authorized thereafter to issue warrants for the purpose of maintaining said fund at the sum of fifty thousand dollars ($50,000.00), but shall only issue said warrants upon the presentation to him of receipted bills of particulars and vouchers, certified by the official or agent of said board having knowledge of the facts upon which the vouchers are based, audited by the secretary and approved by the chairman of the board, and showing the disbursements made by said board out of the aforesaid emergency fund.

SEC. 15. The said board shall, on or before the first day of January in each year, make a full report to the governor of the State of Illinois of all the business transacted by it during the year ending on the preceding 30th day of November, including a statement of all expenditures, contracts entered into, work done, and obligations outstanding or contracted for at the date of the making of each report. The governor shall cause the books and affairs of said board to be audited in each year by an accountant or accountants employed by him for that purpose, and the cost of such audit shall be paid as a part of the cost of the work authorized by this act, upon a voucher approved by the governor.

SEC. 16. Said board shall have power from time to time to lease any water power developed from the water passing through said deep waterway, or canal, subject to the following conditions:

No lease shall be made of any water power until the machinery and appliances for making the same available shall have been constructed and substantially completed. Before any such lease shall be made, at least ninety (90) days' public notice of the intended letting shall be given by publication in a newspaper published in the city of Springfield, and also in the city of Chicago, and such other notice as the board shall deem best. The said board shall have power to require the bids to be accompanied by security, and may reject all bids not satisfactory to them and readvertise until they receive satisfactory bids, whereupon they shall lease said power to the highest and best bidder. No lease shall be for a period exceeding ten (10) years, but the said board may provide for not more than one extension of any lease for a further period of ten (10) years, at a rent to be fixed by appraisal to be made by three disinterested appraisers, to be selected or appointed in such manner as shall be provided in the lease. Said board shall also have power to lease from time to time any of the lands or lots acquired by said board, upon the same terms and subject to the same limitation as are hereinbefore provided in regard to water power.

SEC. 17. All rents and other moneys received by the said board, from the operation of the aforesaid public works, after defraying the cost of maintenance and repair, shall be deposited in the State treasury as a separate fund, to be known as the waterway sinking fund, which shall be kept and used to meet the interest and principal falling due upon said bonds, and to be used by said board, in its discretion, in buying up for cancellation any of said bonds before maturity at not more than the par value thereof, together with accrued interest thereon. The method of disbursing the said waterway sinking fund shall be the same as is hereinbefore provided for the disbursement of the proceeds of the said bonds issued in aid of the original construction of said public works.

SEC. 18. When the channel shall have been completed in conformity with the provision of sections No. 1 and No. 5 hereof, or so much of said channel shall have been built as can be paid for with the proceeds of the $20,000,000.00 of bonds authorized to be sold under the provisions of section 13 hereof, then the said channel, or so much thereof as shall have been completed, shall be tendered to the Government of the United States for navigable uses, conditioned upon the obligation or agreement of said Government to maintain the channel for navigation and to operate and maintain the locks free of cost to the State of Illinois. For all uses other than navigation the channel and its appurtenances shall be, and forever remain, the property of the State of Illinois.